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TEST REPORT # 315160
LSR Job #: C-2234

Compliance Testing of:

TiS10-TiS65

Test Date(s):
June 25th to July 6th 2015

Prepared For:
Attention: Kyle Lundequam
Fluke Corporation
3550 Annapolis Lane N#70
Minneapolis, MN 55447

This Test Report is issued under the Authority of:
Tom Smith, VP of EMC Test Services

Signature: Date: 8-11-15

Test Report Reviewed by:
Tom Smith, VP of EMC Test Services

Signature: Date: 8-11-15

Project Engineer:
Khairul Aidi Zainal, Senior EMC Engineer.

Signature: Date: 7/23/15

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EXHIBIT 1. INTRODUCTION

1.1 - Scope

References:	FCC Part 15, Subpart C, Section 15.247 RSS GEN issue 4 and RSS 247 issue 1
Title:	FCC : Telecommunication – Code of Federal Regulations, CFR 47, Part 15. IC : Digital Transmission Systems (DTSs), Frequency Hopping Systems (FHSs) and Licence-Exempt Local Area Network (LE-LAN) Devices
Purpose of Test:	To gain FCC and IC Certification Authorization for Low-Power License-Exempt Transmitters.
Test Procedures:	Radiated Measurements were conducted in accordance with American National Standards Institute ANSI C63.4 – American National Standard for Methods of Measurement of Radio-Noise Emissions from Low-Voltage Electrical and Electronic Equipment in the Range of 9 kHz to 40 GHz.

1.2 – Normative References

Publication	Year	Title
47 CFR, Parts 0-15 (FCC)	2015	Code of Federal Regulations - Telecommunications
RSS 247 Issue 1	2015	Digital Transmission Systems (DTSs), Frequency Hopping Systems (FHSs) and Licence-Exempt Local Area Network (LE-LAN) Devices
ANSI C63.4	2014	American National Standard for Methods of Measurement of Radio-Noise Emissions from Low-Voltage Electrical and Electronic Equipment in the Range of 9 kHz to 40 GHz.
ANSI 63.10	2013	American National Standard For Testing Unlicensed Wireless devices.
FCC DA 00-705	2000	Filing and Measurement Guidelines for Frequency Hopping Spread Spectrum Systems.
RSS-GEN Issue 4	2014	General Requirements and Information for the Certification of Radio Apparatus

1.3 - LS Research, LLC Test Facility

LS Research, LLC is accredited by A2LA (American Association for Laboratory Accreditation) as conforming to ISO/IEC 17025, 2005 “General Requirements for the Competence of Calibration and Testing Laboratories”.

1.4 – Location of Testing

All testing was performed at the following location utilizing the facilities listed below, unless otherwise noted.

LS Research, LLC
W66 N220 Commerce Court
Cedarburg, Wisconsin, 53012 USA,

List of Facilities Located at LS Research, LLC:

Semi-Anechoic Chamber

1.5 – Test Equipment Utilized

A complete list of equipment utilized in testing is provided in Appendix A of this test report. Calibration dates are indicated in Appendix A. All test equipment is calibrated by a calibration laboratory accredited to the requirements of ISO/IEC 17025, and traceable to the SI standard.

EXHIBIT 2. PERFORMANCE ASSESSMENT

2.1 – Client Information

Manufacturer Name:	Fluke Corporation
Address:	3550 Annapolis Lane N#70, Minneapolis, MN 55447
Contact Name:	Kyle Lundequam

2.2 - Equipment Under Test (EUT) Information

The following information has been supplied by the applicant.

Product Name:	Thermal Imager
Model Number:	TiS10-65
Serial Number:	TiS65-15069005: Radiated measurements A15050019: Conducted measurements

2.3 - Associated Antenna Description

The antenna associated with the EUT is a Johanson Technology high frequency ceramic chip antenna, part number 2450AT18B100. The chip antenna has a peak gain of 0.5dBi.

2.4 - EUT'S Technical Specifications

EUT Frequency Range (in MHz)	2402 MHz to 2480MHz
RF Power in Watts	☒ Conducted Measurement ☐ EIRP
Minimum(Watts):	GFSK = 0.0024Watts EDR 2 = 0.0028Watts EDR 3 = 0.0028Watts
Maximum(Watts):	GFSK = 0.0027Watts EDR 2 = 0.0030Watts EDR 3 = 0.0031Watts
Occupied Bandwidth (99% and 20dB)	20dB (kHz): GFSK = 889.4 EDR 2 = 1362.0 EDR3 = 1350.0 99%(kHz): GFSK = 859.4 EDR 2 = 1213.5 EDR3 = 1215.2
Type of Modulation	GFSK, QPSK
Transmitter Spurious (worst case radiated) at 3 meters	52.1dBµV/m at 7440.0MHz
Stepped (Y/N)	N
Step Value:	N/A
Frequency Tolerance %, Hz, ppm	Better than 100 ppm
Antenna Information	
Detachable/non-detachable	Non-detachable
Type	Ceramic chip antenna
Gain	0.5 dBi peak
EUT will be operated under FCC Rule Part(s)	Title 47 part 15.247
EUT will be operated under RSS Rule Part(s)	RSS 247
Modular Filing	☐ Yes ☒ No
Portable or Mobile?	Portable

RF Technical Information:

Type of Evaluation (check one)		SAR Evaluation: Device Used in the Vicinity of the Human Head
		SAR Evaluation: Body-worn Device
	X	RF Evaluation

The EUT was evaluated against the SAR test exclusion threshold listed in KDB 447498 D01 General RF Exposure Guidance v05r02, section 4.3 (1). The EUT was found to be compliant with the SAR exclusion threshold, 10-g extremity, for 100MHz to 6000MHz.

Frequency = 2.402 GHz
ERP (dBm) = 4.9 dBm
ERP (mW)= 3.1 milliwatt
Minimum separation distance = less than 5 mm

[3.1mw/5mm]*[√2.48GHz] = 0.62*1.55 = **0.96 ≤ 7.5**

When evaluated against RSS 102 issue 5 section 2.5, table 1:

Frequency = 2.402 GHz
EIRP (dBm) = 4.9 + 0.5 dBm
EIRP (mW)= **3.5 milliwatt**

Interpolating between 1900 and 2450 MHz for 2402 MHz at separation distance of 5 mm yields exemption limit of 4.3mW

Applying the limb-worn 10 gram value multiply by a factor of 2.5 = 4.3*2.5 = 10.8mW

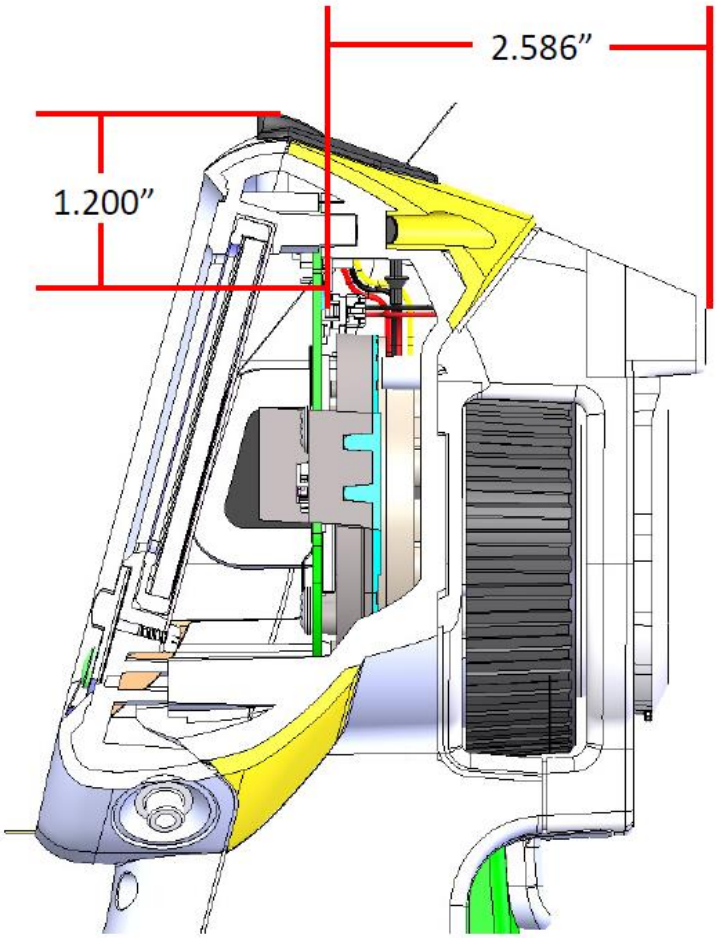
SAR test exclusion requirement is satisfied.

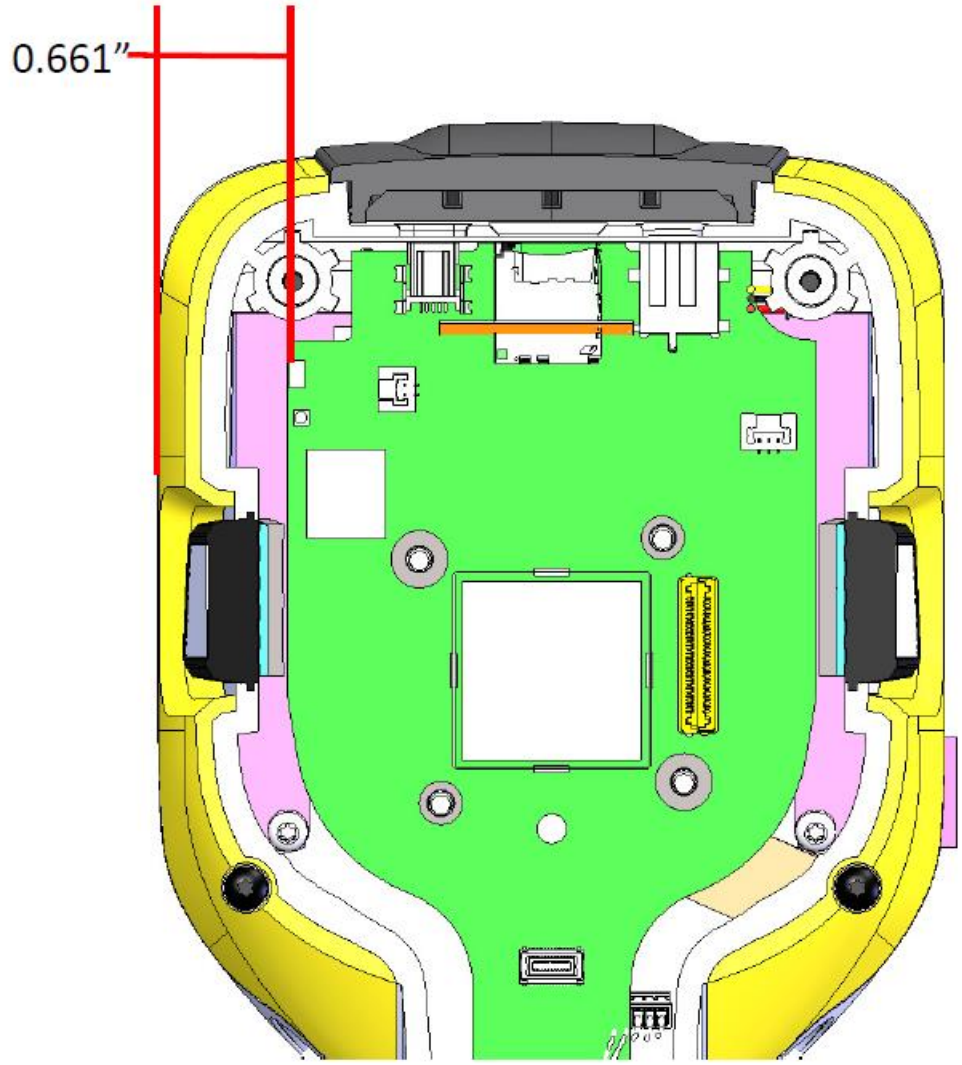
Table 1: SAR evaluation – Exemption limits for routine evaluation based on frequency and separation distance[4,5]

Frequency (MHz)	Exemption Limits (mW)				
	At separation distance of ≤5 mm	At separation distance of 10 mm	At separation distance of 15 mm	At separation distance of 20 mm	At separation distance of 25 mm
≤300	71 mW	101 mW	132 mW	162 mW	193 mW
450	52 mW	70 mW	88 mW	106 mW	123 mW
835	17 mW	30 mW	42 mW	55 mW	67 mW
1900	7 mW	10 mW	18 mW	34 mW	60 mW
2450	4 mW	7 mW	15 mW	30 mW	52 mW
3500	2 mW	6 mW	16 mW	32 mW	55 mW
5800	1 mW	6 mW	15 mW	27 mW	41 mW

The EUT antenna separation distance to the extremity is greater than 15 mm (refer to figure below), hence is excluded from SAR.

ANTENNA LOCATION 1 – All Models





Note: Bluetooth and WLAN radios do not transmit at the same time. Please refer to Appendix D for BT and WLAN Coexistence information.

2.5 - Product Description

The Fluke, TiS10, TiS20, TiS40, TiS45, TiS50, TiS55, TiS60, and TiS65 Thermal Imagers (the Product or Imager) are handheld, infrared imaging cameras for use in many applications. These applications include equipment troubleshooting, preventive and predictive maintenance, building diagnostics, and research and development. All Imagers display thermal images on a high-visibility, industrial-quality (320X240) LCD touch screen and can save images to a removable memory card. Saved images and data can be transferred through the memory card to a PC, a direct USB connection to the PC, or by wireless transfer to a PC or mobile device. The TiS family has two mechanical versions: The TiS10, TiS20, TiS40, TiS50, and TiS60 use a fixed focus IR lens. The TiS45, TiS55, and TiS65 use a manual focus lens, which includes an external focus ring.

EXHIBIT 3. EUT OPERATING CONDITIONS & CONFIGURATIONS DURING TESTS

3.1 - Climate Test Conditions

Temperature:	70-71° F
Humidity:	34-38%
Pressure:	729-742mmHg

3.2 - Applicability & Summary Of EMC Emission Test Results

FCC and IC Paragraph	Test Requirements	Compliance (Yes/No)
FCC : 15.207 IC : RSS GEN sect. 7.2.2	Power Line Conducted Emissions Measurements	Yes
FCC : 15.247 (a)(1) IC : RSS 210 A8.1 (a)	20 dB Bandwidth	Yes
FCC : 15.247(b) & 1.1310 IC : RSS 247 section 5.4	Maximum Output Power	Yes
FCC : 15.247(i), 1.1307, 1.1310, 2.1091 & 2.1093 IC : RSS 102	RF Exposure Limit	Yes
FCC :15.247(d) IC : RSS 247 section 5.5	RF Conducted Spurious Emissions at the Transmitter Antenna Terminal	Yes
FCC:15.247 (a)(1)(iii) IC: RSS 257 Section 5.1	Carrier Frequency Separation	Yes
FCC:15.247 (a)(1)(i),(ii),(iii) IC: RSS 247 Section 5.1	Number of hopping channels	Yes
FCC:15.247 (a)(1)(i),(ii),(iii) IC: RSS 247 Section 5.1	Time of occupancy (Dwell Time)	Yes
FCC : 15.247(b) IC : RSS GEN	Transmitter Radiated Emissions in the restricted bands	Yes

3.3 - Modifications Incorporated In The EUT For Compliance Purposes

☒ None ☐ Yes (explain below)

3.4 - Deviations & Exclusions From Test Specifications

☒ None ☐ Yes (explain below)

EXHIBIT 4. DECLARATION OF CONFORMITY

The EUT was found to MEET the requirements as described within the specification of FCC Title 47, CFR Part 15.247, and Industry Canada RSS-247, Issue 1.

Note: If some emissions are seen to be within 3 dB of their respective limits; as these levels are within the tolerances of the test equipment and site employed, there is a possibility that this unit, or a similar unit selected out of production may not meet the required limit specification if tested by another agency.

LS Research, LLC certifies that the data contained herein was taken under conditions that meet or exceed the requirements of the test specifications. The results in this Test Report apply only to the item(s) tested on the above-specified dates. Any modifications made to the EUT subsequent to the indicated test date(s) will invalidate the data herein, and void this certification.

EXHIBIT 5. RADIATED EMISSIONS TEST

5.1 - Test Setup

The test setup was assembled in accordance with Title 47, CFR FCC Part 15, RSS GEN and ANSI C63.10-2013. The EUT was placed on an 80cm high non-conductive pedestal below 1 GHz and 150cm above 1 GHz, centered on a flush mounted turntable inside a 3 meter Semi-Anechoic, FCC listed Chamber. The EUT was operated in continuous transmit mode for final testing using power as provided by an AC to DC power supply that comes with the EUT. The unit has the capability to operate on 3 channels, controllable via proprietary software provided by the manufacturer.

The applicable limits apply at a 3 meter distance. The calculations to determine these limits are detailed in the following pages. Please refer to Appendix A for a complete list of test equipment. The test sample was operated on one of three (3) standard channels to comply with FCC Part 15.31(m).

5.2 - Test Procedure

Radiated RF measurements were performed on the EUT in a 3 meter Semi-Anechoic, FCC listed Chamber. The frequency range from 30 MHz to 25000 MHz was scanned and investigated. The radiated RF emission levels were manually noted at the various fixed degree settings of azimuth on the turntable and antenna height. The EUT was placed on a non-conductive pedestal in the 3 meter Semi-Anechoic Chamber, with the antenna mast placed such that the antenna was 3 meters from the EUT. A Biconical Antenna was used to measure emissions from 30 MHz to 300 MHz, and a Log Periodic Antenna was used to measure emissions from 300 MHz to 1000 MHz. A Double-Ridged Waveguide Horn Antenna was used from 1 GHz to 18 GHz while a standard gain horn antenna was used in the 18 GHz to 25 GHz range. The maximum radiated RF emissions between 30MHz to 25 GHz were found by raising and lowering the sense antenna between 1 and 4 meters in height, using both horizontal and vertical antenna polarities.

The EUT was positioned in 3 orthogonal orientations.

5.3 - Test Equipment Utilized

A list of the test equipment and antennas utilized for the Radiated Emissions test can be found in Appendix A. This list includes calibration information and equipment descriptions. All equipment is calibrated and used according to the operation manuals supplied by the manufacturers. All calibrations of the antennas used were performed at a calibration laboratory accredited to ISO 17025, and are traceable to the SI standard. In addition, the Connecting Cables were measured for losses using a calibrated Signal Generator and an EMI Receiver. The resulting correction factors and the cable loss factors from these calibrations were entered into the EMI Receiver database. **As a result, the data taken from the EMI Receiver accounts for the antenna correction factor as well as cable loss or other corrections, and can therefore be entered into the database as a corrected meter reading.** The EMI Receiver was operated with a resolution bandwidth of 120 kHz for measurements below 1 GHz (video bandwidth of 300 kHz), and a bandwidth of 1 MHz for measurements above 1 GHz (video bandwidth of 1 MHz).

5.4 - Test Results

The EUT was found to **MEET** the Radiated Emissions requirements of Title 47 CFR, FCC Part 15.247 and Canada RSS-247, Issue 1, for an FHSS transmitter. The frequencies with significant RF signal strength were recorded and plotted as shown in the Data Charts and Graphs.

5.5 - Calculation of Radiated Emissions Limits and reported data

Reported data:

For both fundamental and spurious emissions measurement, the data reported includes all necessary correction factors. These correction factors are loaded onto the EMI receiver when measurements are performed.

Reported Measurement data = Raw receiver measurement (dBµV/m) + Antenna correction Factor + Cable factor (dB) + Miscellaneous factors when applicable (dB) – amplification factor when applicable (dB).

Generic example of reported data at 200 MHz:

Reported Measurement data = 18.2 (raw receiver measurement) + 15.8 (antenna factor) + 1.45 (cable factor) = 35.45 (dBµV/m).

As specified in 15.247 (d), radiated emissions that fall within the restricted band described in 15.205(c), must comply with the general emissions limit.

The following table depicts the general radiated emission limits above 30 MHz. These limits are obtained from Title 47 CFR, Part 15.209, for radiated emissions measurements. These limits were applied to any signals found in the 15.205 restricted bands. The mentioned limits correspond to those limits listed in RSS GEN.

Frequency (MHz)	3 m Limit µV/m	3 m Limit (dBµV/m)	1 m Limit (dBµV/m)
30-88	100	40.0	-
88-216	150	43.5	-
216-960	200	46.0	-
960-24,000	500	54.0	63.5

Sample conversion of field strength (µV/m to dBµV/m):
To convert 100 µV/m to dBµV/m,

dBµV/m = 20 $\log_{10}$ (100)= 40 dBµV/m (from 30-88 MHz)

5.6 - Radiated Emissions Test Data Chart

Manufacturer:	Fluke					
Date(s) of Test:	July 1st -2nd 2015					
Project Engineer(s):	Khairul Aidi Zainal					
Test Engineer(s):	Khairul Aidi Zainal					
Voltage:	120VAC					
Operation Mode:	continuous transmit, modulated					
Environmental Conditions in the Lab:	Temperature: 70-71˚F Relative Humidity: 34-38%					
EUT Power:	X	Single Phase 120VAC		3 Phase ___VAC		
		Battery		Other: Bench DC supply		
EUT Placement:	**X**	80cm non-conductive pedestal	**X**	150cm non-conductive pedestal		
EUT Test Location:	**X**	3 Meter Semi-Anechoic FCC Listed Chamber		3/10m OATS		
Measurements:		Pre-Compliance		Preliminary	**X**	Final
Detectors Used:	**X**	Peak	**X**	Quasi-Peak	**X**	Average

Frequency (MHz)	Ant	EUT	Height (cm)	Azimuth (°)	Peak (dBuV/m)	Q.Peak (dBuV/m)	Average (dBuV/m)	Peak limit (dBuV/m)	Q.Peak limit (dBuV/m)	Average limit (dBuV/m)	Peak margin (dB)	Q.Peak margin (dB)	Average margin (dB)	Note
1041.7	H	V	195.4	215	52.2	N/A	45.0	74.0	N/A	54.0	21.8	N/A	9.0	1.0
7320.0	H	F	287.8	241	56.4	N/A	50.7	74.0	N/A	54.0	17.6	N/A	3.3	
12200.0	H	F	219.6	25	60.4	N/A	52.0	74.0	N/A	54.0	13.6	N/A	2.0	
7440.0	H	F	299.0	280	57.5	N/A	52.1	74.0	N/A	54.0	16.5	N/A	1.9	
12010.0	H	F	225.2	31	59.3	N/A	52.0	74.0	N/A	54.0	14.7	N/A	2.1	
12400.0	H	F	247.8	32	59.9	N/A	51.8	74.0	N/A	54.0	14.1	N/A	2.2	
4804.0	V	S	243.0	333	43.5	N/A	35.1	74.0	N/A	54.0	30.5	N/A	18.9	
4880.0	V	S	100.0	342	46.1	N/A	37.4	74.0	N/A	54.0	27.9	N/A	16.6	
4960.0	V	S	130.0	343	43.9	N/A	36.0	74.0	N/A	54.0	30.1	N/A	18.0	
194.4	H	V	100.0	118	N/A	31.2	N/A	N/A	43.0	N/A	N/A	11.8	N/A	1.0
38.4	V	V	100.0	212	N/A	31.8	N/A	N/A	40.0	N/A	N/A	8.2	N/A	1.0
420.0	H	V	100.0	143	N/A	40.0	N/A	N/A	46.0	N/A	N/A	6.0	N/A	1.0
592.0	V	V	100.0	19	N/A	44.7	N/A	N/A	46.0	N/A	N/A	1.3	N/A	1.0
560.0	V	V	100.0	330	N/A	45.9	N/A	N/A	46.0	N/A	N/A	0.1	N/A	1.0

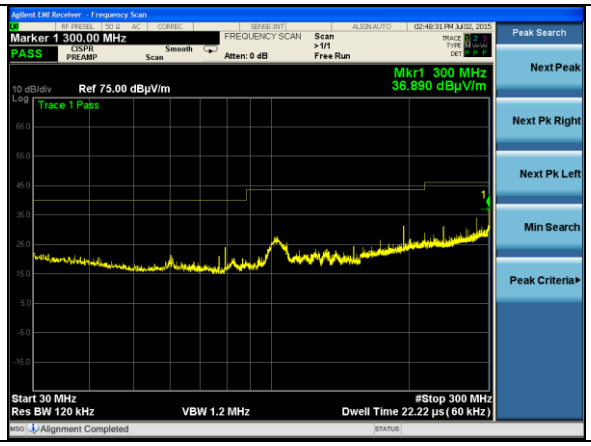
Notes:

1. Not a transmitter related emission.
2. H: Horizontal, V: Vertical, S: Side, F: Flat.
3. Refer to exhibit 5.5 on explanation of how data is reported.

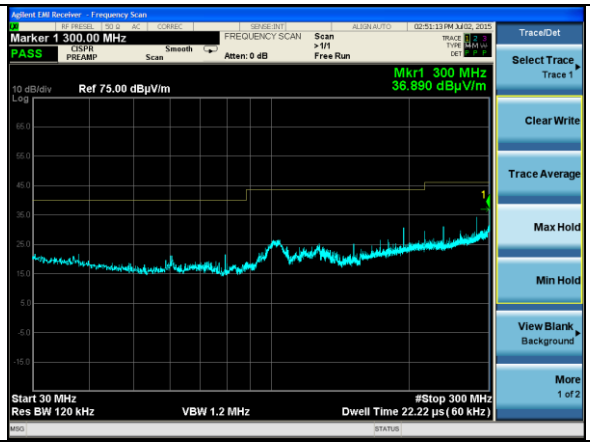
5.7 – Screen Captures.

The screen captures below are those using the Peak detector of the analyzer. In addition, the screen captures presented are those which were deemed to be an appropriate representation of the spectrum scan.

30 to 300 MHz, 3m distance.

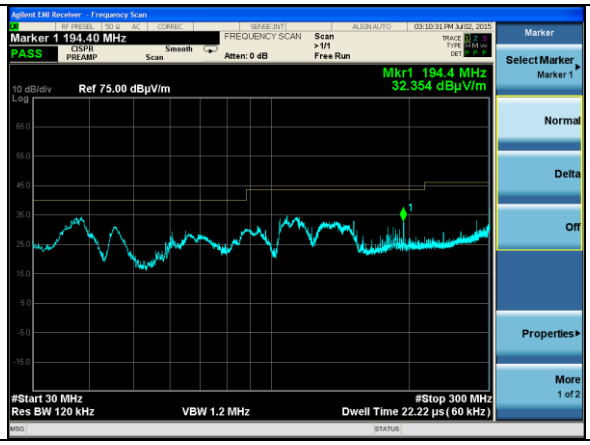


Horizontal Transmitter enabled



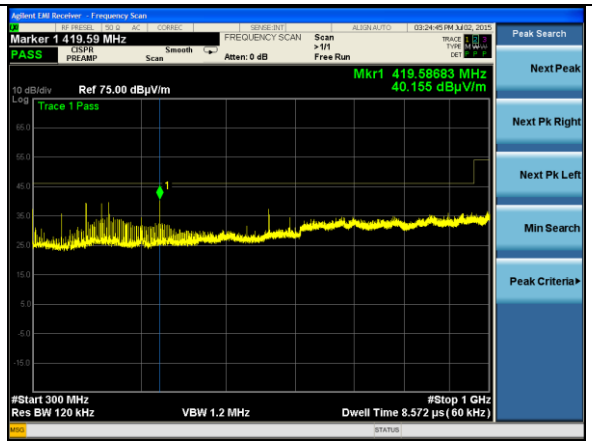
Horizontal Transmitter disabled

Vertical Transmitter enabled

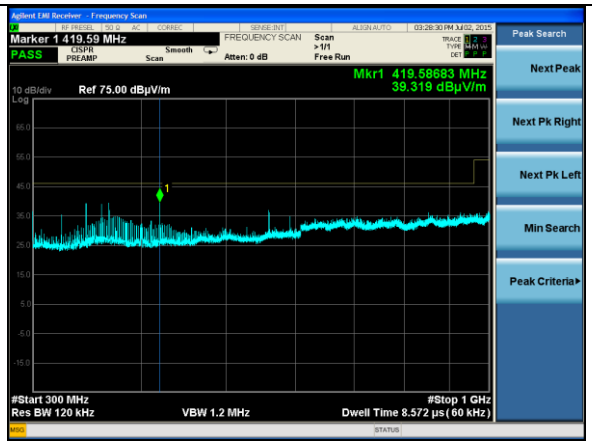


Vertical Transmitter disabled

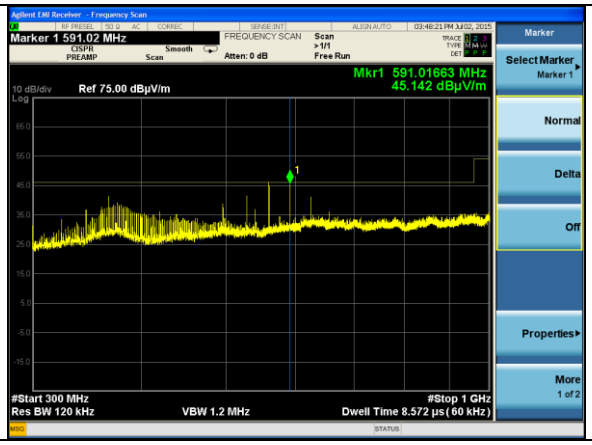
300 to 1000 MHz, 3m distance.



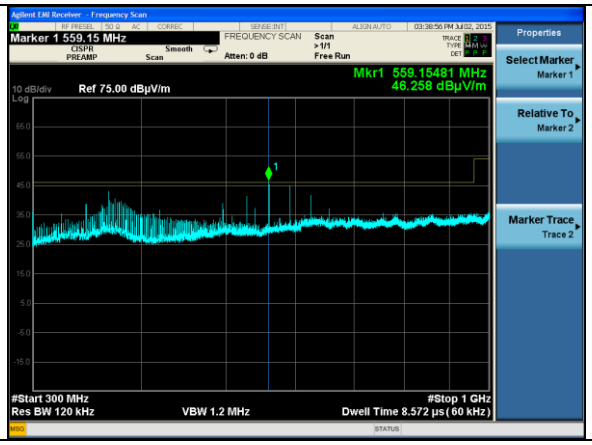
Horizontal Transmitter enabled



Horizontal Transmitter disabled

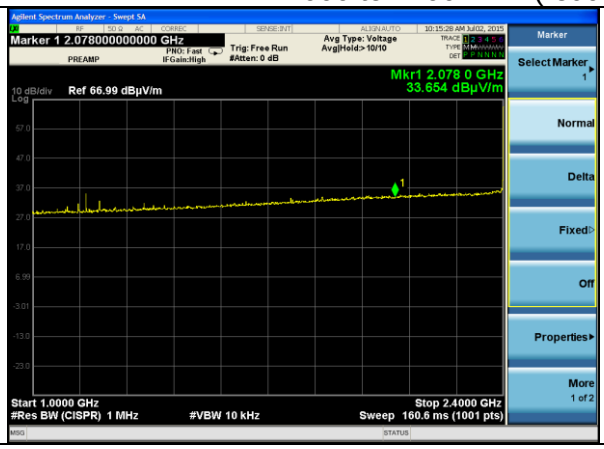


Vertical Transmitter enabled

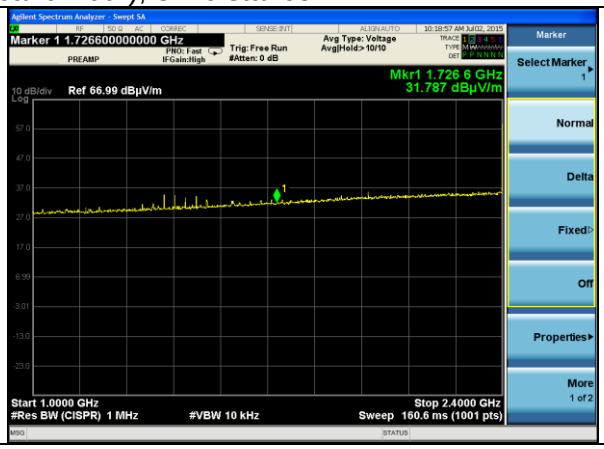


Vertical Transmitter disabled

1000 to 2400 MHz (reduced bandwidth), 3m distance.

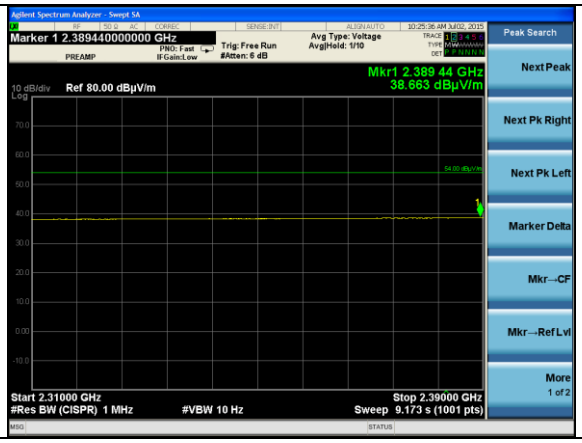


Horizontal

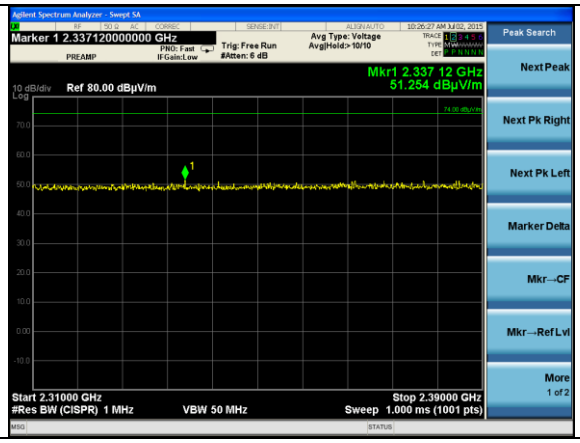


Vertical

2310 to 2390 MHz, 3m distance.



Average



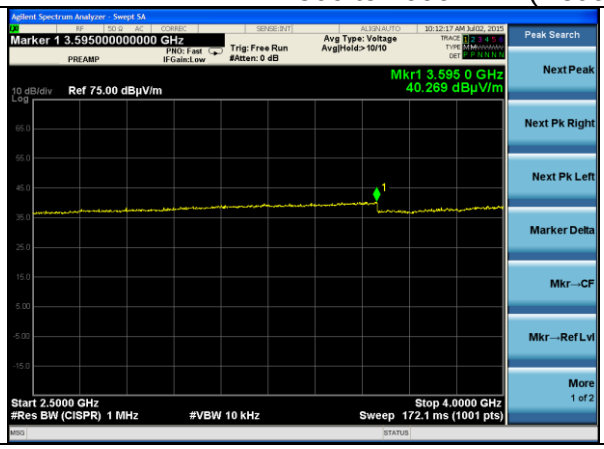
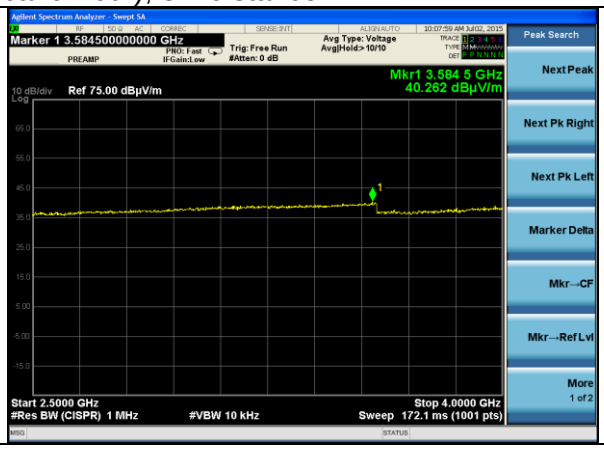
Peak

Notes:

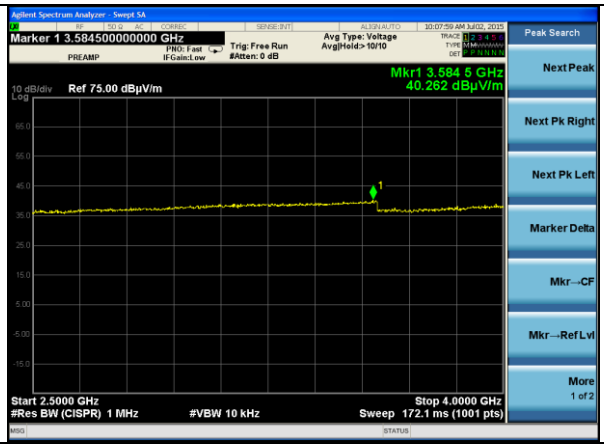
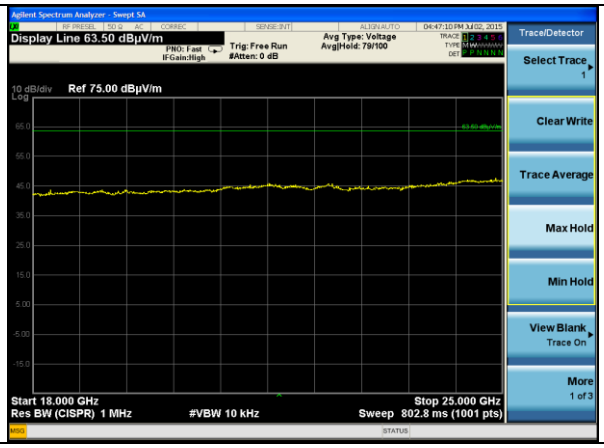
1. The plot above taken when EUT was in basic rate mode and represents worst case. EDR2 and EDR3 modes were tested and found to be lower in emission.
2. Table below shows points on the plot of the maximum emission:

Peak Frequency (MHz)	Peak (dBuV/m)	Peak limit (dBuV/m)	Peak Margin (B)	Average Frequency (MHz)	Average (dBuV/m)	Average limit (dBuV/m)	Average Margin (B)
2337.1	51.3	74.0	22.7	2389.4	38.7	54.0	15.3

2500 to 4000 MHz (Reduced bandwidth), 3m distance.

	
Horizontal	Vertical

4000 to 25000 MHz.

	
4000 to 18000 MHz (reduced bandwidth)	18000 to 25000 MHz (reduced bandwidth at 1 m distance)

Note: The range 2483.5 to 2500 MHz is in section 8 of this report (Band-edges).

EXHIBIT 6. CONDUCTED EMISSIONS TEST, AC POWER LINE

6.1 Test Setup

The test area and setup are in accordance with ANSI C63.4 and with Title 47 CFR, FCC Part 15, Industry Canada RSS GEN. The EUT was placed on a non-conductive wooden table, with a height of 80 cm above the reference ground plane. The power supply was then plugged into a 50Ω (ohm), Line Impedance Stabilization Network (LISN). The AC power supply of 120V was provided via an appropriate broadband EMI Filter, and then to the LISN line input. Final readings were then taken and recorded. After the EUT was setup and connected to the LISN, the RF Sampling Port of the LISN was connected to a 10 dB Attenuator-Limiter, and then to EMI receiver System. The EMCO LISN used has the ability to terminate the unused port with a 50Ω (ohm) load when switched to either L1 (line) or L2 (neutral).

6.2 Test Procedure

The EUT was investigated in continuous modulated transmit mode for this portion of the testing. The appropriate frequency range and bandwidths were selected on the EMI Receiver, and measurements were made. The bandwidth used for these measurements is 9 kHz, as specified in CISPR 16-1, Section 1, Table 1, for Quasi-Peak and Average detectors in the frequency range of 150 kHz to 30 MHz. Final readings were then taken and recorded.

6.3 Test Equipment Utilized

A list of the test equipment and accessories utilized for the Conducted Emissions test is provided in Appendix A. This list includes calibration information and equipment descriptions. All equipment is calibrated and used according to the operation manuals supplied by the manufacturers. Calibrations of the LISN and Limiter were performed at an IEC/ISO 17025 accredited calibration laboratory, traceable to the SI standard. All cables are calibrated and checked periodically for conformance. The emissions are measured on the EMI System, which has automatic correction for all factors stored in memory and allows direct readings to be taken.

6.4 Test Results

The EUT was found to **MEET** the Conducted Emission requirements of FCC Part 15.207 and RSS GEN 7.2.4 for Conducted Emissions for an Intentional Radiator. See the Data Charts and Graphs for more details of the test results.

6.5 FCC Limits of Conducted Emissions at the AC Mains Ports

Frequency Range (MHz)	Class A Limits (dBµV)		Measuring Bandwidth
	Quasi-Peak	Average	
0.150 -0.50 *	66-56	56-46	RBW = 9 kHz VBW ≥ 9 kHz for QP VBW = 1 Hz for Average
0.5 – 5.0	56	46	
5.0 – 30	60	50	
* The limit decreases linearly with the logarithm of the frequency in this range.			

6.6 CONDUCTED EMISSIONS TEST DATA CHART

Manufacturer:	Fluke					
Date(s) of Test:	9/11/15					
Project Engineer:	Khairul Aidi Zainal					
Test Engineer:	Aidi Zainal					
Voltage:	120 VAC and 230VAC					
Operation Mode:	Continuous transmit, modulated					
Environmental Conditions in the Lab:	Temperature: 71˚ F Relative Humidity: 40%					
Test Location:	X	AC Mains Test area				Chamber
EUT Placed On:	X	40cm from Vertical Ground Plane				10cm Spacers
	X	80cm above Ground Plane				Other:
Measurements:		Pre-Compliance		Preliminary	X	Final
Detectors Used:		Peak	X	Quasi-Peak	X	Average

120VAC, 60Hz

		Quasi-Peak			Average		
Frequency (MHz)	Line	Q-Peak Reading (dBµV)	Q-Peak Limit (dBµV)	Quasi-Peak Margin (dB)	Average Reading (dBµV)	Average Limit (dBµV)	Average Margin (dB)
0.159	1	46.7	65.5	18.8	32.0	55.5	23.5
0.347	1	44.9	59.0	14.1	36.2	49.0	12.8
3.952	1	38.6	56.0	17.4	30.8	46.0	15.2
5.392	1	33.2	60.0	26.8	25.4	50.0	24.6
0.159	2	46.0	65.5	19.5	30.5	55.5	25.0
0.455	2	42.6	56.8	14.2	32.6	46.8	14.2
3.871	2	38.8	56.0	17.2	31.5	46.0	14.5
5.922	2	34.1	60.0	25.9	26.6	50.0	23.4

Notes:

1) The emissions listed are characteristic of the power supply used and not that of the transmitter. Changing transmit channels did not change the emissions.

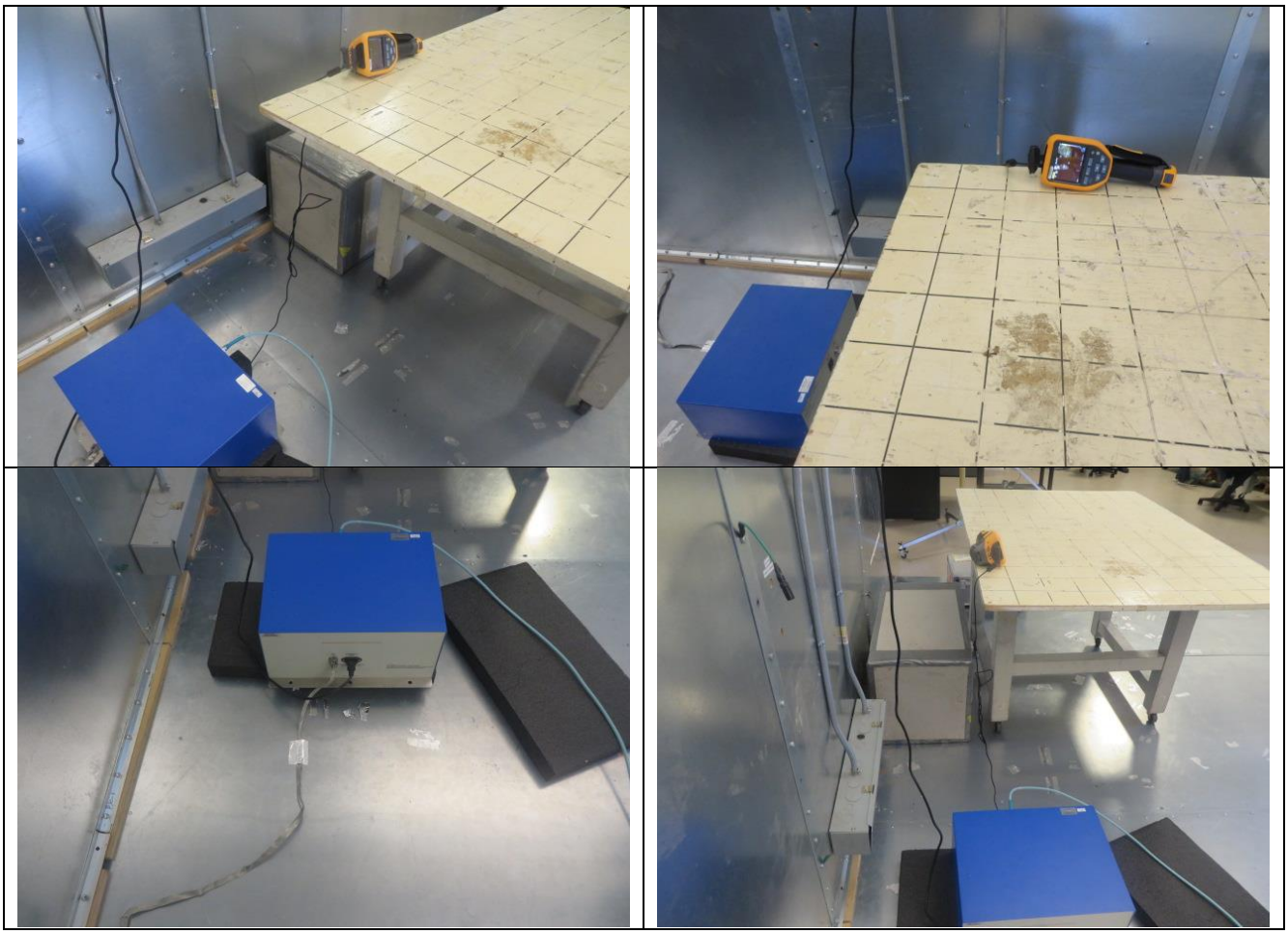
230VAC, 50Hz

		Quasi-Peak			Average		
Frequency (MHz)	Line	Q-Peak Reading (dBµV)	Q-Peak Limit (dBµV)	Quasi-Peak Margin (dB)	Average Reading (dBµV)	Average Limit (dBµV)	Average Margin (dB)
0.173	1	46.3	64.8	18.5	37.3	54.8	17.5
0.406	1	45.3	57.7	12.4	34.0	47.7	13.7
0.604	1	42.9	56.0	13.1	33.3	46.0	12.7
0.995	1	42.3	56.0	13.7	33.1	46.0	12.9
0.159	2	44.2	65.5	21.3	32.7	55.5	22.8
0.397	2	45.1	57.9	12.8	35.3	47.9	12.6
0.512	2	43.0	56.0	13.0	34.4	46.0	11.6
0.995	2	42.8	56.0	13.2	33.7	46.0	12.3

Notes:

1) The emissions listed are characteristic of the power supply used and not that of the transmitter. Changing transmit channels did not change the emissions.

6.7 Test Setup Photo(s) – Conducted Emissions Test



6.8 Screen Captures – Conducted Emissions Test

These screen captures represent Peak Emissions. For conducted emission measurements, both a Quasi-Peak detector function and an Average detector function are utilized.

120 VAC, 60Hz

Line 1

Line 2

230 VAC, 50Hz

Line 1

Line 2

EXHIBIT 7. OCCUPIED BANDWIDTH

7.1 - Limits

For an FHSS system operating in the 2400 to 2483.5 MHz band, there are no limits for 20dB bandwidth.

7.2 - Method of Measurements

Industry Canada (IC RSS GEN 4.6.1) requires the measurement of the 99% bandwidth while CFR 47 part 15.247 requires the measurement of the 20dB bandwidth. For this portion of the tests, a direct measurement of the transmitted signal was performed at the antenna port of the EUT, via a cable connection to a spectrum analyzer. An attenuator was placed in series with the cable to protect the spectrum analyzer. The loss from the cable and the attenuator were added on the analyzer as gain offset settings there by allowing direct measurements, without the need for any further corrections. The EUT was configured to run in a continuous transmit mode, while being supplied with typical data as a modulation source. A bandwidth measurement function that is built into the spectrum analyzer was used to measure the bandwidths.

Measurement procedure: FCC DA 00-705

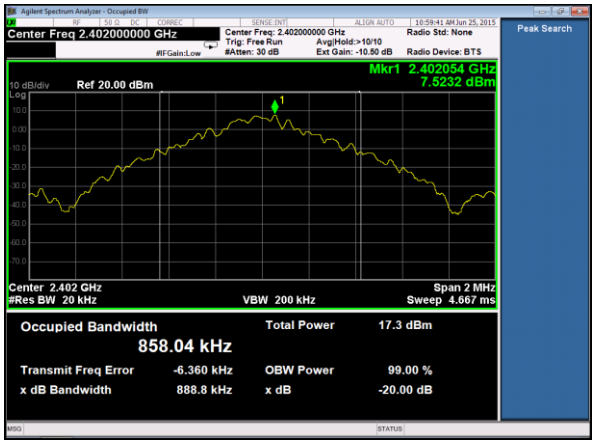
7.3 - Test Data

Packet Type	Channel	Frequency (MHz)	20dB EBW (kHz)	99% EBW (kHz)
GFSK	1	2402	888.8	858.0
	39	2440	889.4	858.4
	79	2480	889.0	859.4
EDR2	1	2402	1362.0	1213.5
	39	2440	1358.0	1211.6
	79	2480	1361.0	1213.4
EDR3	1	2402	1350.0	1215.2
	39	2440	1349.0	1214.5
	79	2480	1348.0	1213.6

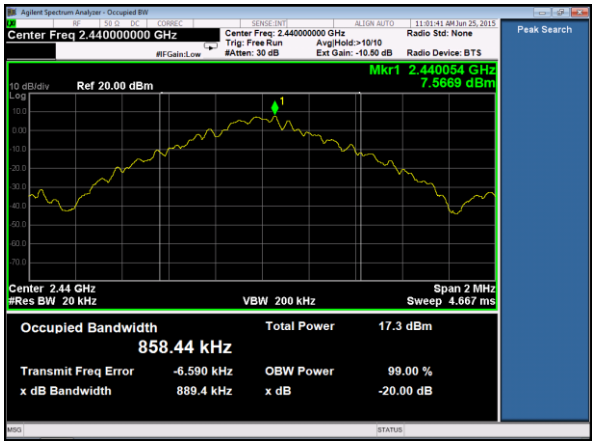
7.4 – Screen Captures

A. GFSK

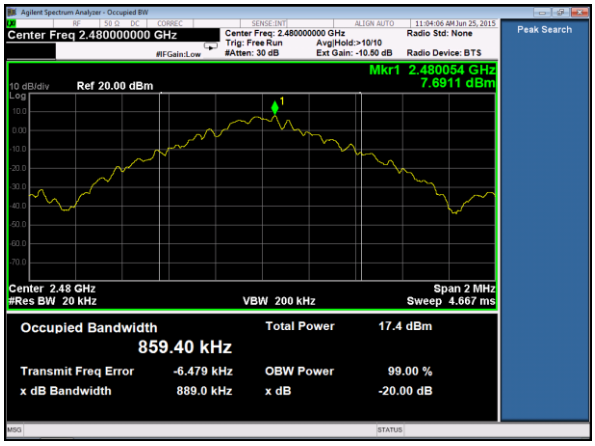
Channel 2402MHz



Channel 2440MHz

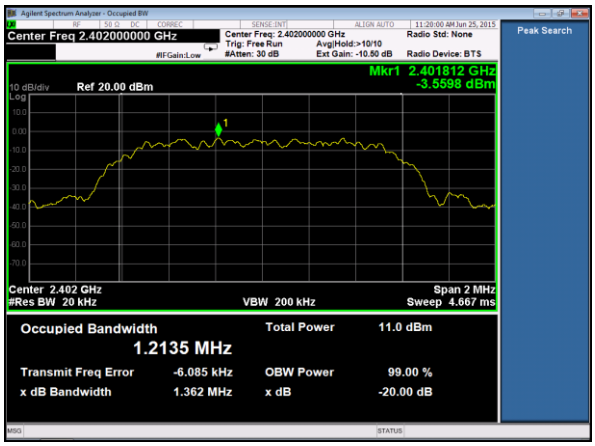


Channel 2480MHz

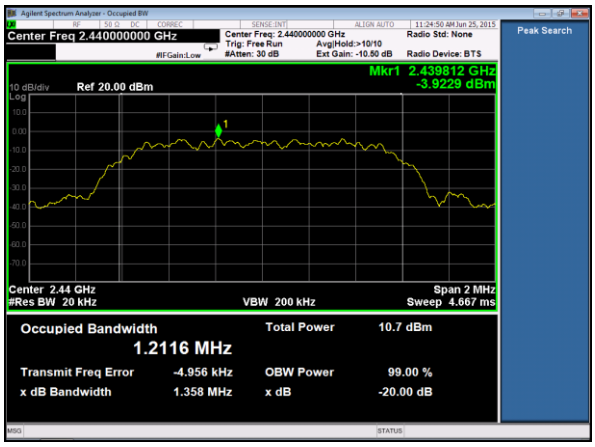


B. EDR2

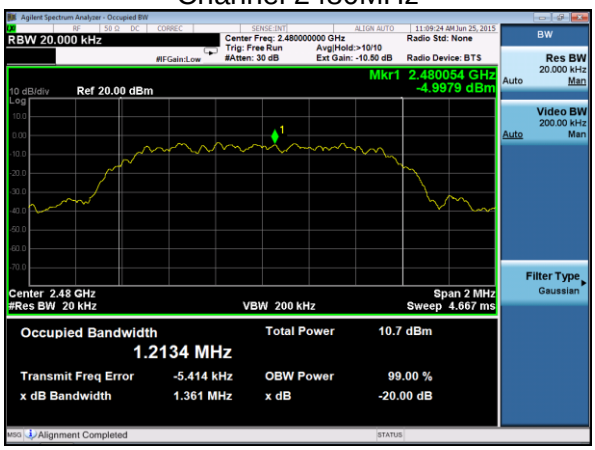
Channel 2402MHz



Channel 2440MHz

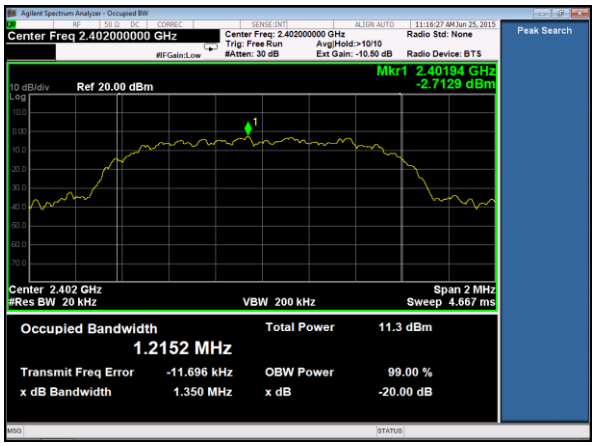


Channel 2480MHz

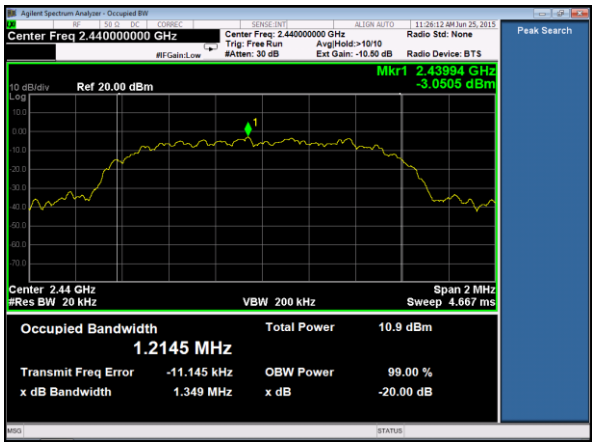


C. EDR3

Channel 2402MHz



Channel 2440MHz



Channel 2480MHz

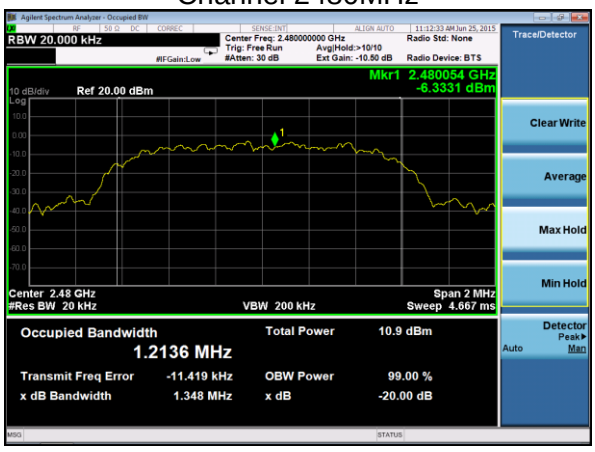


EXHIBIT 8. BAND EDGE MEASUREMENTS

8.1 - Method of Measurements

FCC 15.247 requires a measurement of spurious emission levels at the restricted band to be compliant to the general emissions limit, in particular at the Band-Edges where the intentional radiator operates. The EUT was operated in continuous transmit mode with continuous modulation, with internally generated data as the modulating source. The EUT was operated at the lowest channel for the investigation of the lower Band-Edge, and at the highest channel for the investigation of the higher Band-Edge.

The Band-edge measurements were performed radiated and conducted. The conducted measurement of band-edge was performed to satisfy FCC 15.247(d). The radiated measurements were performed to satisfy the conditions of 15.205 restricted bands.

Conducted measurements of the spurious emission were performed with a measurement bandwidth of 100kHz while radiated measurements were performed with a measurement bandwidth of 1MHz.

For both conducted and radiated measurements, correction factors and the cable loss factors were entered into the EMI Receiver database. **As a result, the plots taken from the EMI Receiver accounts for all applicable correction factor as well as cable loss, and can therefore be entered into the database as a corrected meter reading.**

Measurement procedure:

1. Conducted measurement: FCC DA 00-705
2. Radiated measurements: ANSI C63.10

8.2. Band-Edge captures.

Radiated Band-edge restricted band (2483.5 to 2500 MHz):

Data:

A. GFSK (Basic rate)

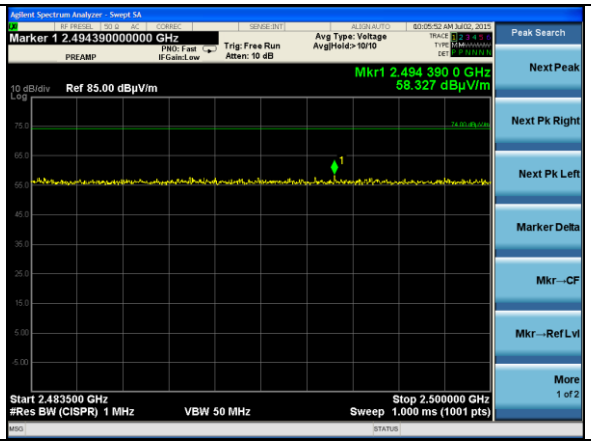
Peak Frequency (MHz)	Peak (dBuV/m)	Peak limit (dBuV/m)	Peak Margin (B)	Average Frequency (MHz)	Average (dBuV/m)	Average limit (dBuV/m)	Average Margin (B)
2494.4	58.3	74.0	15.7	2483.5	37.2	54.0	16.8

B. EDR2 (2MBPS)

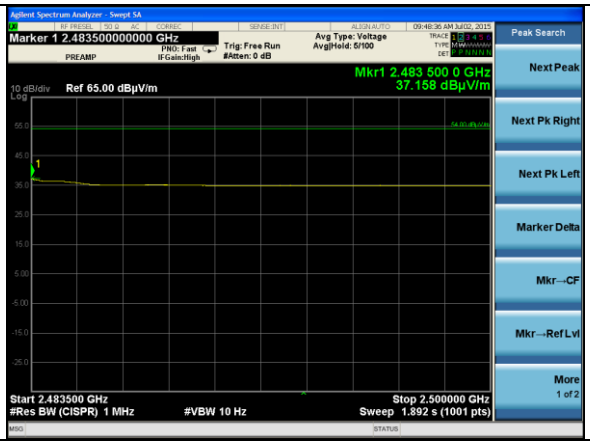
Peak Frequency (MHz)	Peak (dBuV/m)	Peak limit (dBuV/m)	Peak Margin (B)	Average Frequency (MHz)	Average (dBuV/m)	Average limit (dBuV/m)	Average Margin (B)
2496.2	57.7	74.0	16.3	2483.5	37.8	54.0	16.2

C. EDR3 (3MBPS)

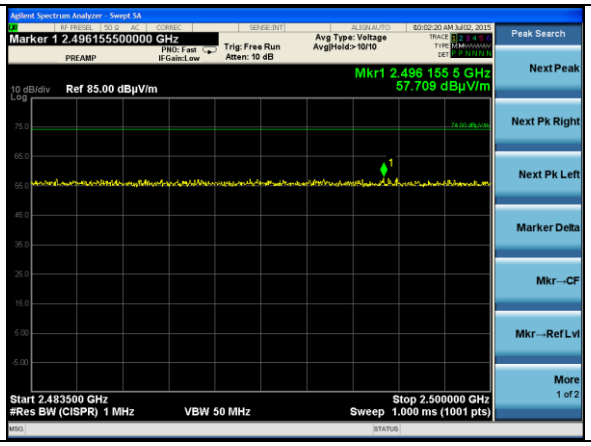
Peak Frequency (MHz)	Peak (dBuV/m)	Peak limit (dBuV/m)	Peak Margin (B)	Average Frequency (MHz)	Average (dBuV/m)	Average limit (dBuV/m)	Average Margin (B)
2498.7	56.9	74.0	17.1	2483.5	37.3	54.0	16.7



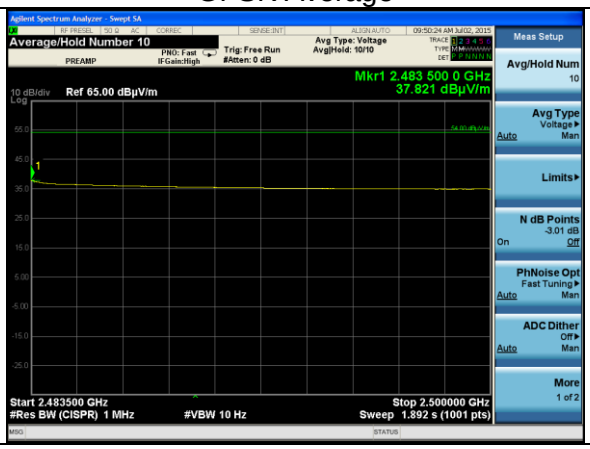
GFSK Peak



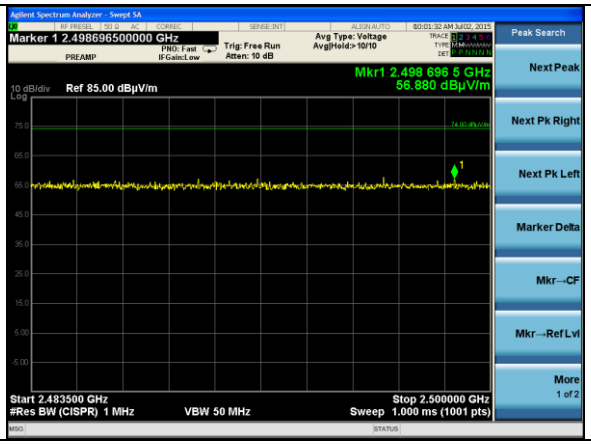
GFSK Average



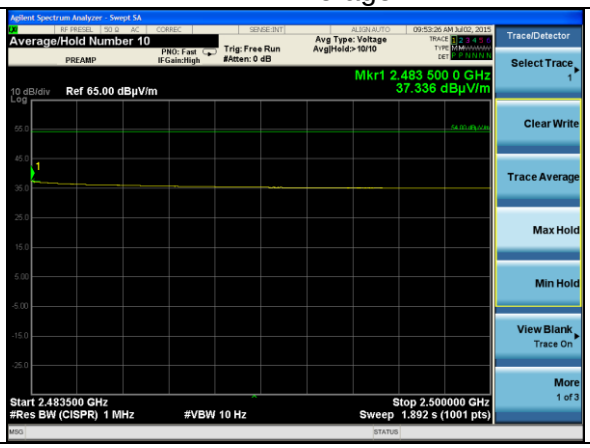
EDR2 Peak



EDR2 Average



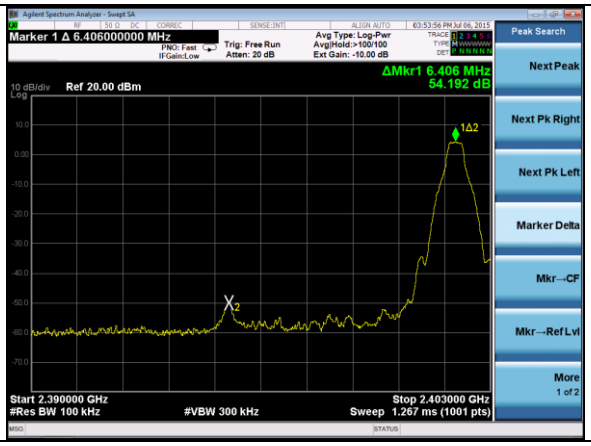
EDR3 Peak



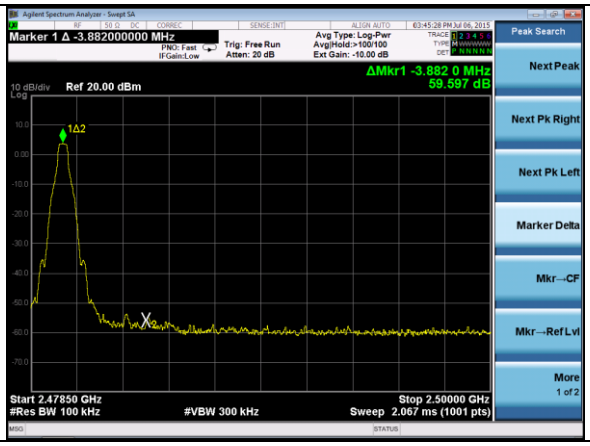
EDR3 Average

Conducted Band-edge:

GFSK

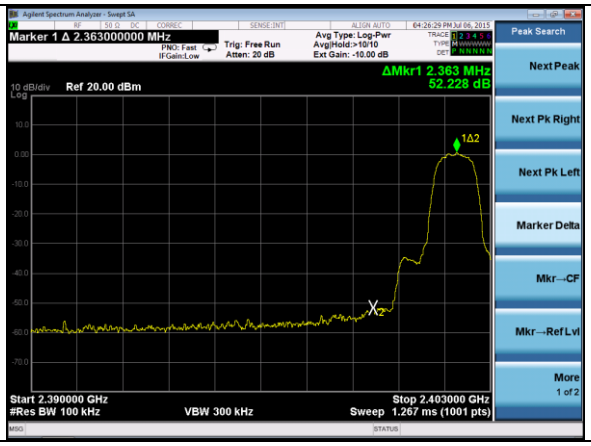


Lower band edge

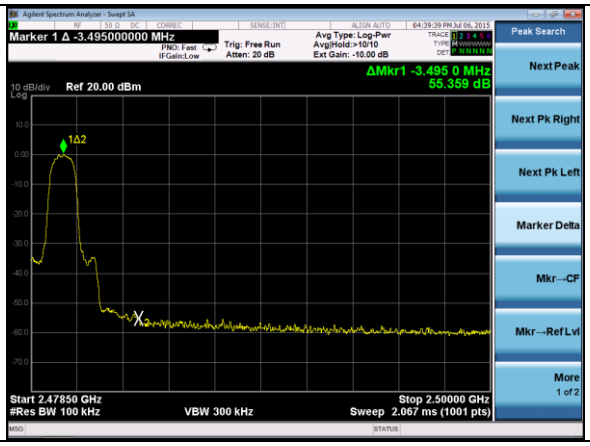


Upper band edge

EDR2

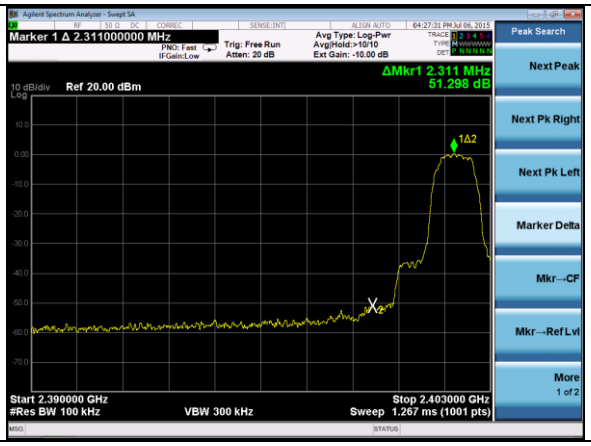
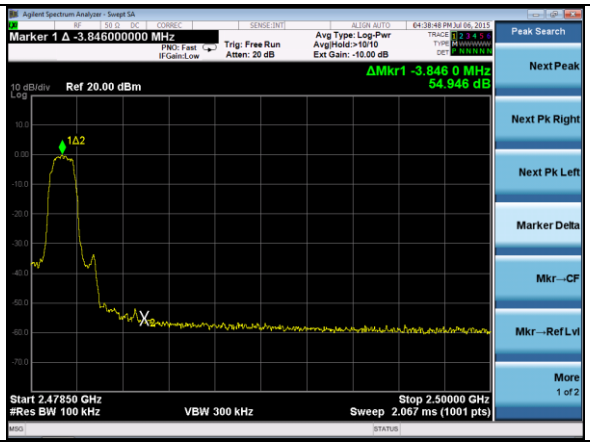


Lower band edge

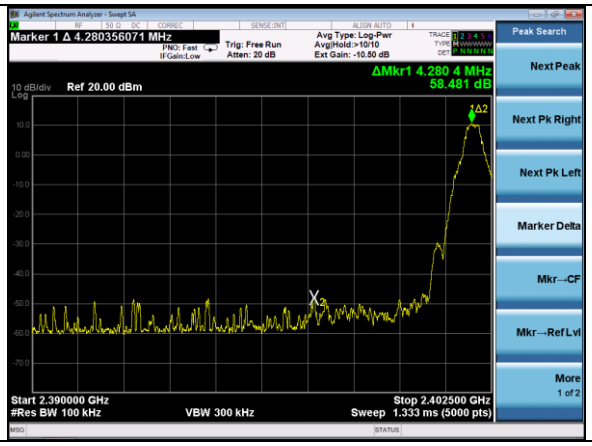


Upper band edge

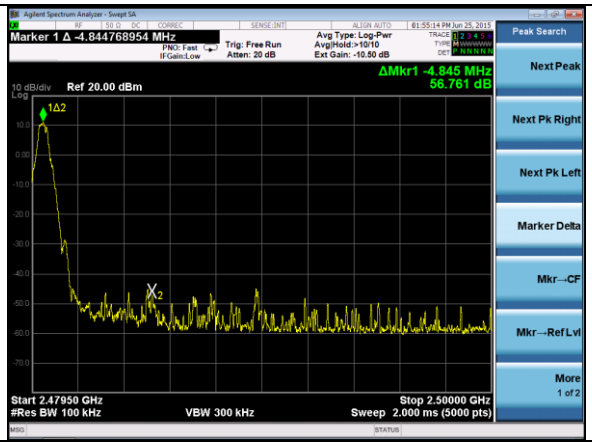
EDR3

	
Lower band edge	Upper band edge

Hopping mode:

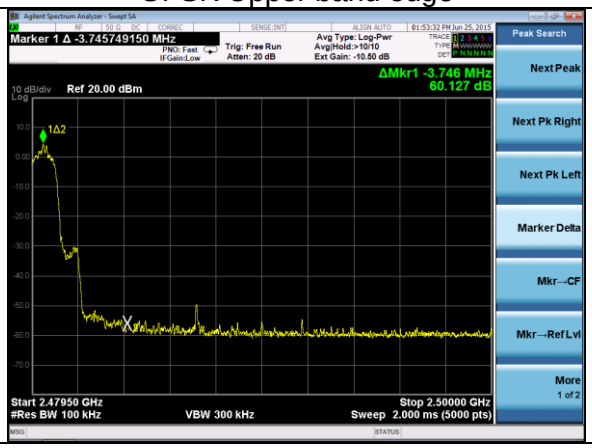


GFSK Lower band edge



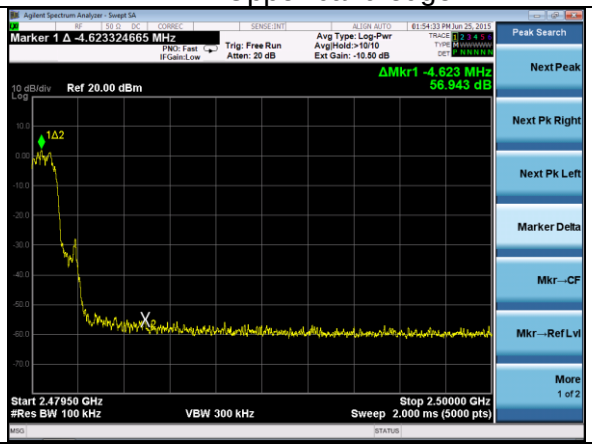
GFSK Upper band edge

EDR2 Lower band edge



EDR2 Upper band edge

EDR3 Lower band edge



EDR3 Upper band edge

EXHIBIT 9. POWER OUTPUT (CONDUCTED): 15.247(b)

9.1 - Method of Measurements

The conducted RF output power of the EUT was measured at the antenna port using a short RF cable along with an attenuator as protection for the spectrum analyzer. The loss from the cable and the attenuator were added on the analyzer as gain offset settings there by allowing direct measurements without the need for any further corrections. The unit was configured to run in a continuous transmit mode, while being supplied with typical data as a modulation source. The spectrum analyzer was used with the appropriate resolution bandwidth, with measurements from a peak detector presented in the chart below.

Measurement procedure: FCC DA 00-705

9.2 - Test Data

Mode	Channel	Frequency (MHz)	Output Power (dBm)	Output power limit (dBm)	Margin (dB)
GFSK	1	2402	4.3	21.0	16.7
	39	2440	4.0	21.0	17.0
	79	2480	3.9	21.0	17.1
EDR2	1	2402	4.8	21.0	16.2
	39	2440	4.5	21.0	16.5
	79	2480	4.4	21.0	16.6
EDR3	1	2402	4.9	21.0	16.1
	39	2440	4.7	21.0	16.3
	79	2480	4.5	21.0	16.5

Note:

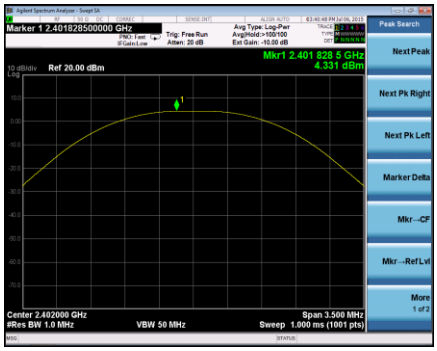
1. Reported data sample calculation (2440 MHz, GFSK):

   Peak Output Power (dBm) = 3.3dBm + 0.7dB = **4.0dBm**

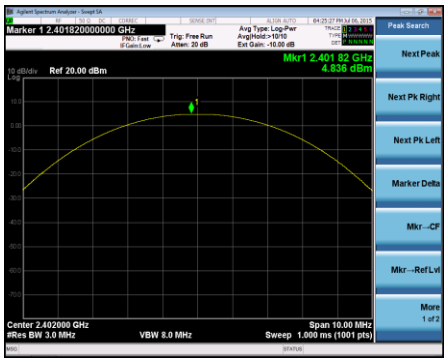
9.3 – Screen Captures

Low Channel (2402 MHz)

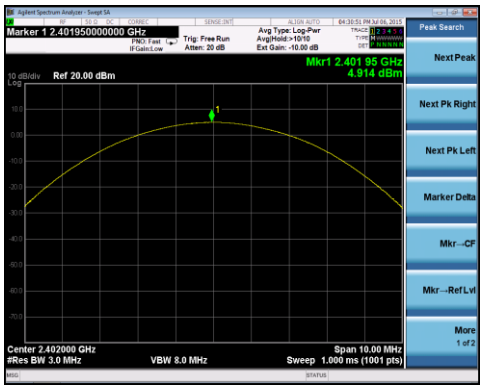
GFSK



EDR2

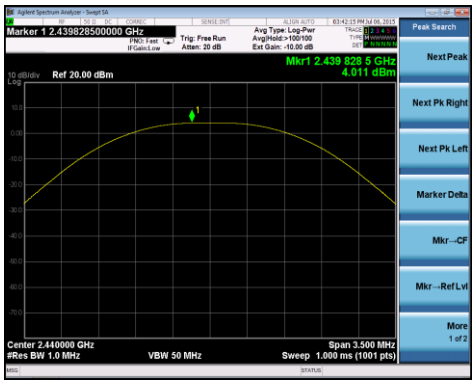


EDR3

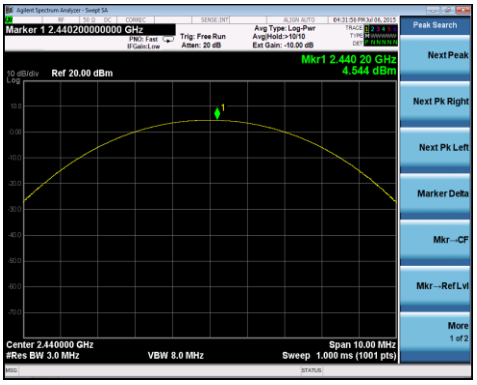


Middle Channel (2440 MHz)

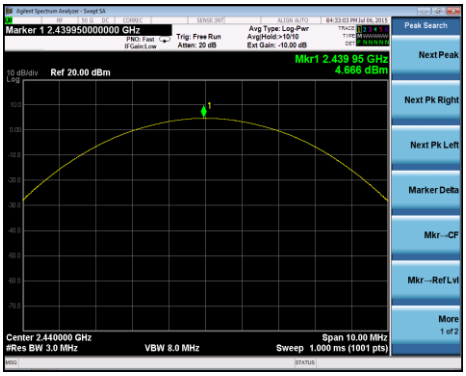
GFSK



EDR2

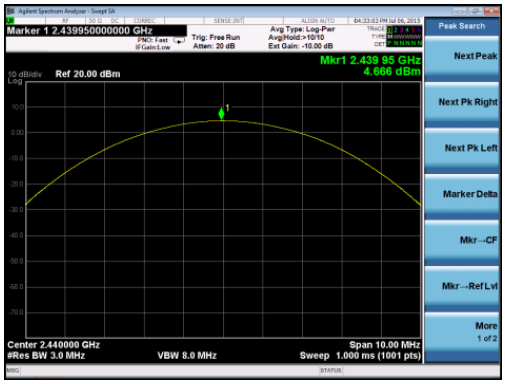


EDR3

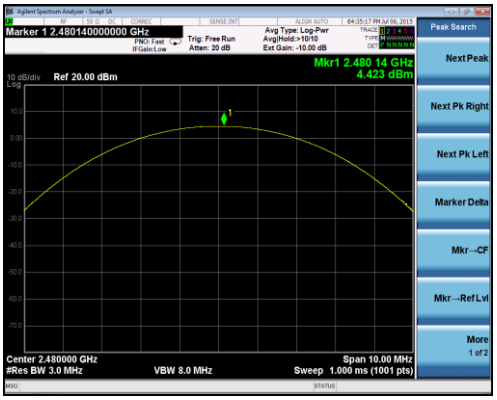


High Channel (2480 MHz)

GFSK



EDR2



EDR3

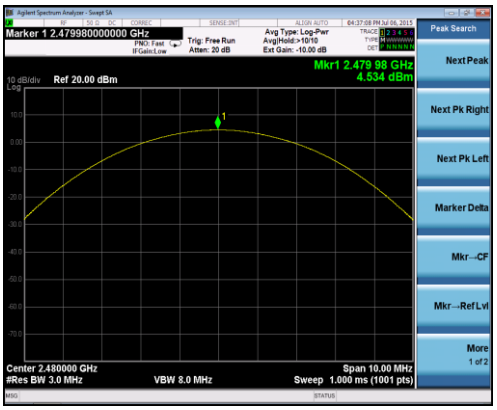


EXHIBIT 10. CONDUCTED SPURIOUS EMISSIONS: 15.247(d)

10.1 - Limits

In any 100 kHz bandwidth outside the frequency band in which the spread spectrum or digitally modulated intentional radiator is operating, the radio frequency power that is produced by the intentional radiator shall be at least 20 dB below that in the 100 kHz bandwidth within the band that contains the highest level of the desired power, based on either an RF conducted or a radiated measurement.

10.2 – Conducted Harmonic And Spurious RF Measurements

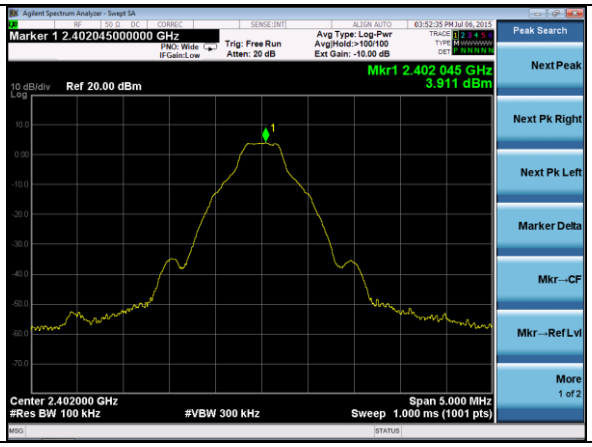
FCC Part 15.247(d) require a measurement of conducted harmonic and spurious RF emission levels, as reference to the carrier level when measured in a 100 kHz bandwidth. For this test, the spurious and harmonic RF emissions from the EUT were measured at the EUT antenna port using a short RF cable along with an attenuator as protection for the spectrum analyzer. The loss from the cable and the attenuator were added on the analyzer as gain offset settings, thereby allowing direct readings of the measurements made without the need for any further corrections. A spectrum analyzer was used with the resolution bandwidth set to 100 kHz for this portion of the tests. The unit was configured to run in a continuous transmit mode, while being supplied with typical data as a modulation source. The spectrum analyzer was used with measurements from a peak detector presented in the chart below. Screen captures were acquired and any noticeable spurious and harmonic signals were identified and measured.

Measurement procedure: FCC DA 00-705

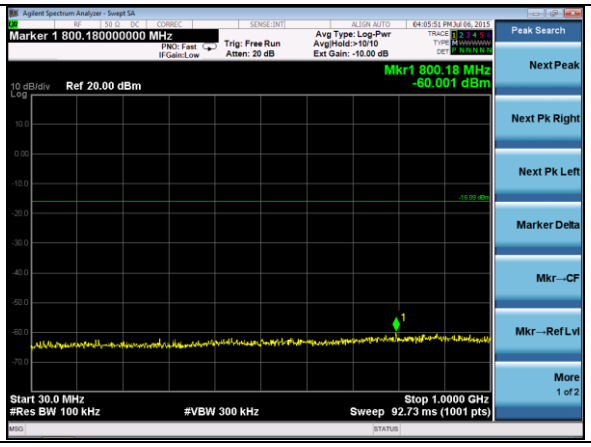
10.3 - Test Data

(Data shown is that of GFSK mode being worst case)

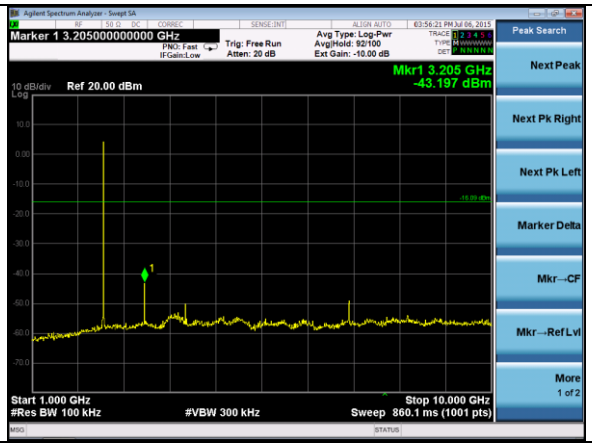
A. Low Channel



Fundamental



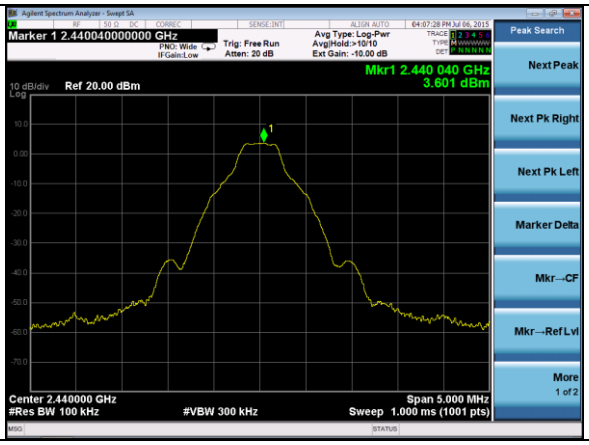
30 to 1000MHz



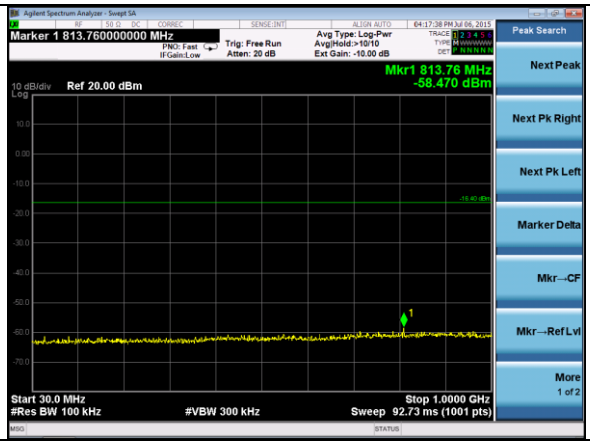
1000 to 10000 MHz

10000 to 25000

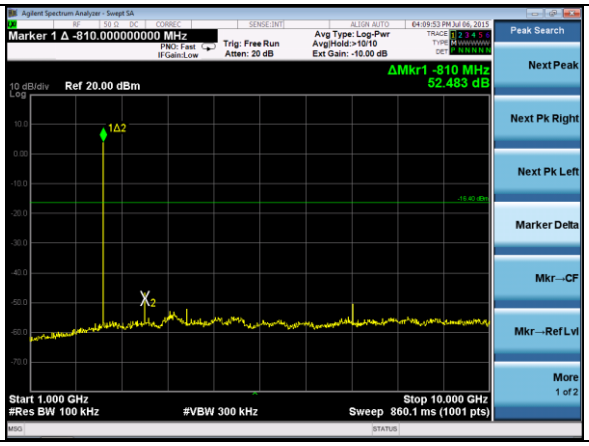
B. Middle Channel



Fundamental



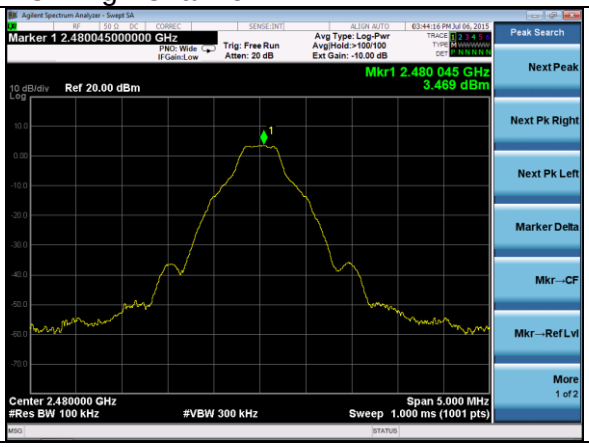
30 to 1000MHz



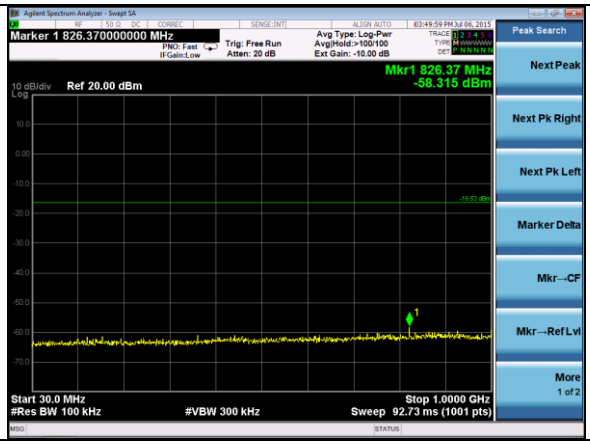
1000 to 10000 MHz

10000 to 25000

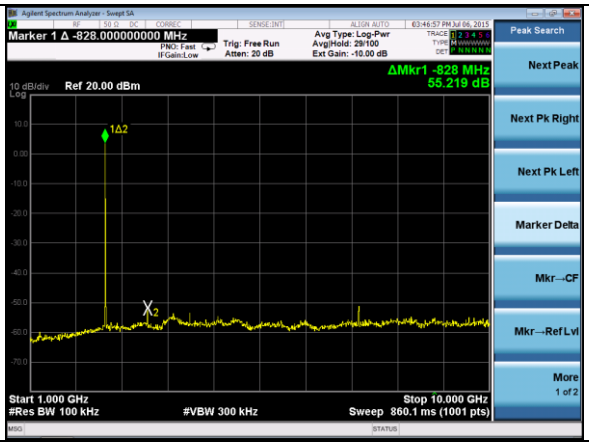
C. High Channel



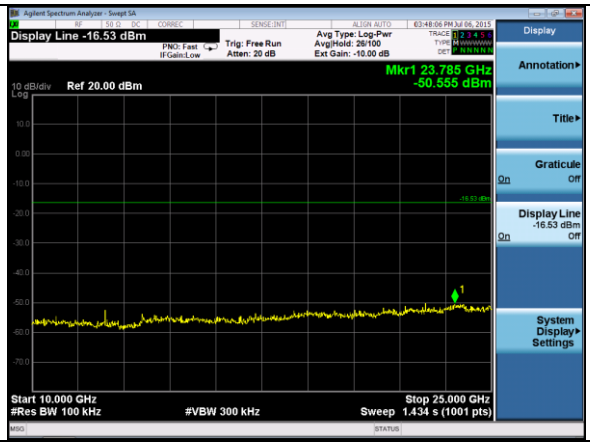
Fundamental



30 to 1000MHz



1000 to 10000 MHz



10000 to 25000

EXHIBIT 11. FREQUENCY & POWER STABILITY OVER VOLTAGE VARIATIONS

The power and frequency stability of the device was examined as a function of the input voltage available to the EUT. A Spectrum Analyzer was used to measure the power and frequency at the appropriate frequency markers. Power was supplied by an external bench-type DC power supply and was varied ±10% from the nominal.

BLUETOOTH

	13.5VDC	15.0VDC	16.5VDC	
	FREQUENCY (Hz)	FREQUENCY (Hz)	FREQUENCY (Hz)	FREQ DRIFT (Hz)
LOW CHANNEL	2401995037	2401995053	2401995031	22
MID CHANNEL	2439994987	2439995007	2439994994	20
HIGH CHANNEL	2479994853	2479994851	2479994863	12

The power was then cycled On/Off to observe system response. No unusual response was observed, the emission characteristics were well behaved, and the system returned to the same state of operation as before the power cycle.

EXHIBIT 12. CHANNEL PLAN AND SEPARATION

A spectrum analyzer was used with a resolution bandwidth of 1% of the span to measure the channel separation of the EUT.

Measurement procedure: FCC DA 00-705

The channel separation measured for this device **1000.0 kHz** which is greater than 2/3 of the 20dB bandwidth. The maximum 20dB bandwidth of the device, as reported in the previous section is 1369 kHz, therefore 2/3 of the 20dB bandwidth = 912.0 kHz. The following plots describe this spacing, and also establish the channel separation and plan.

This EUT also satisfies the minimum number of hopping channels which is 15.

Span	Number of channels
2400 to 2441 MHz	39.0
2441 to 2483 MHz	40.0

Total Number of channels	79.0

12.1 - Screen Captures

Channel Separation

Number of channels

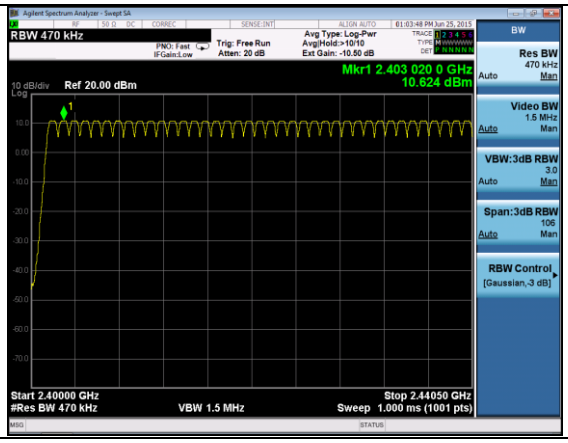
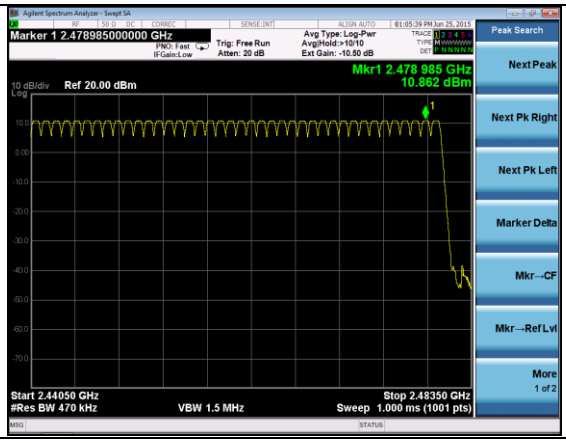
	
2400 – 2441 MHz	2441 – 2483 MHz

EXHIBIT 13. CHANNEL OCCUPANCY.

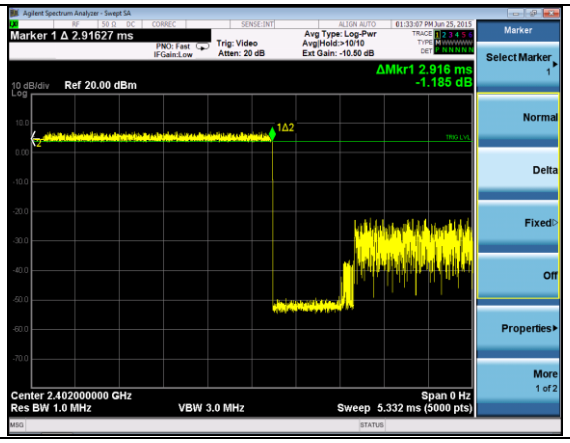
Measurement procedure: FCC DA 00-705

Part 15.247(a)(1)(i) requires an average channel occupancy, for this device, of no more than 400 milliseconds in a 31.6 second window .The channel occupancy for this EUT was measured using a spectrum analyzer, set to zero-span at the frequency of interest. With the analyzer in peak-hold mode, the transmission lengths can be measured by adjusting the sweep rate of the analyzer. A suitable sweep rate was used to measure the channel occupancy at the low, mid and high channels. The longest time a single transmission will occur on a single channel is **2.916 ms**. The number of occurrences in a **10 seconds** window is **38.** In a 31.6 seconds window, there will be 380 occurrences. Therefore the total time occupancy in a 31.6 seconds window is

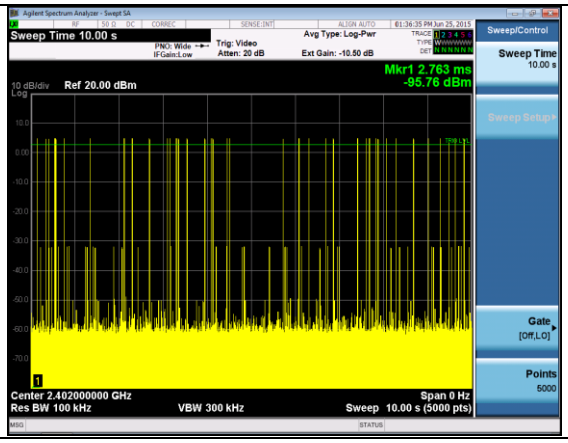
380 x 2.916ms = **350.2ms**

13.1 Time occupancy captures.

(The captures shown are from EDR3 mode which is worst case, lowest channel)



Single transmission



Maximum Occupancy in 7.9s

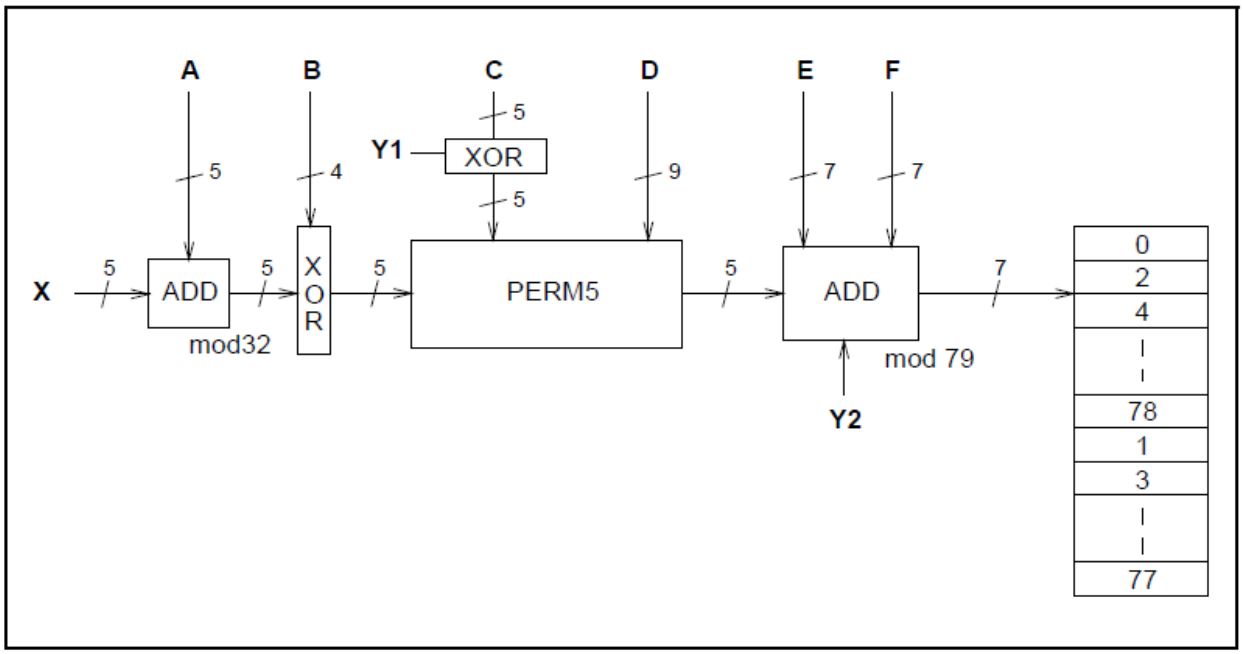
EXHIBIT 14. EQUAL CHANNEL USAGE

The transceiver implemented in the EUT is a Bluetooth core specification V2.1 + EDR hence satisfies this requirement.

EXHIBIT 15. PSEUDORANDOM HOPPING SEQUENCE.

(Supplied by Customer; referencing Bluetooth Core specifications.)

Bluetooth devices use a hopping kernel to generate a hopping map. The figure below represents the basic hop selection kernel for the hop system. The output of the adder addresses a bank of 79 registers. The registers are loaded with the synthesizer code words corresponding to the hop frequencies 0 to 78. Note that the upper half of the bank contains the even hop frequencies, whereas the lower half of the bank contains the odd hop frequencies.



The X input determines the phase in the 32-hop segment, whereas Y1 and Y2 selects between master-to-slave and slave-to-master. The inputs A to D determine the ordering within the segment, the inputs E
and F determine the mapping onto the hop frequencies. The kernel addresses a register containing the RF channel indices. This list is ordered so that first all even RF channel indices are listed and then all odd hop frequencies. In this way, a 32-hop segment spans about 64 MHz and visits these hops in a pseudo-random order. Next, a different 32-hop segment is chosen, etc. When the basic channel hopping sequence is selected, the output constitutes a pseudo-random sequence that slides through the 79 hops. The principle is depicted below:

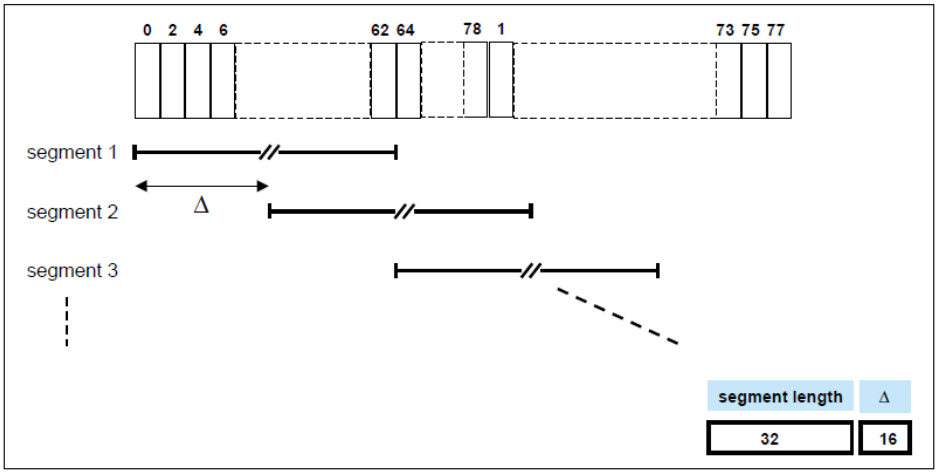

0 2 4 6
62 64
78 1
73 75 77
segment 1
segment 2
Δ
segment 3
segment length
Δ
32
16

EXHIBIT 16. RECEIVER SYNCHRONIZATION AND INPUT BANDWIDTH.

(Referencing Bluetooth Core specifications.)

During the pairing process, the Master sets the data rate with the slave device. This will then determine the bandwidth of the receiver input. If a request is made for a change in data rate after pairing, the receiver bandwidth changes accordingly. This is set in the Bluetooth protocol.

During typical operation a physical radio channel is shared by a group of devices that are synchronized to a common clock and frequency hopping pattern. One device provides the synchronization reference and is known as the master. All other devices synchronized to a master's clock and frequency hopping pattern are known as slaves. A group of devices synchronized in this fashion form a piconet. This is the fundamental form of communication in the Bluetooth BR/EDR wireless technology.

Devices in a piconet use a specific frequency hopping pattern, which is algorithmically determined by certain fields in the Bluetooth address and clock of the master. The basic hopping pattern is a pseudo-random ordering of the 79 frequencies, separated by 1 MHz, in the ISM band. The hopping pattern can be adapted to exclude a portion of the frequencies that are used by interfering devices.

Each packet starts with an access code. If a packet header follows, the access code is 72 bits long, otherwise the access code is 68 bits long. This access code is used for synchronization, DC offset compensation and identification. The access code identifies all packets exchanged on the channel of the piconet: all packets sent in the same piconet are preceded by the same channel access code. In the receiver of the Bluetooth unit, a sliding correlator correlates against the access code and triggers when a threshold is exceeded. This trigger signal is used to determine the receive timing.

Slaves maintain an estimate of the master's native clock by adding a timing offset to the slave's native clock. This offset shall be updated each time a packet is received from the master. By comparing the
exact RX timing of the received packet with the estimated RX timing, slaves shall correct the offset for any timing misalignments. Since only the channel access code is required to synchronize the slave, slave RX timing can be corrected with any packet sent in the master-to-slave transmission slot.

APPENDIX A – Test Equipment List

LS RESEARCH LLC
Wireless Product Development
Equipment Calibration

Date : 18-Jun-2015 Type Test : Conducted measurements Job # : C-2234

Prepared By: Aidi Customer : Fluke Thermography Quote #: 315160

No.	Asset #	Description	Manufacturer	Model #	Serial #	Cal Date	Cal Due Date	Equipment Status
1	EE 960087	44GHz EXA Spectrum Analyzer	Agilent	N9010A	MY53400296	12/11/2014	12/11/2015	Active Calibration
2	AA 960143	Phaseflex	Gore	EKD01D01048.0	5546519	6/14/2013	6/14/2015	Active Calibration
3	AA 960144	Phaseflex	Gore	EKD01D010720	5800373	Verification	Verification	System

Project Engineer: Quality Assurance:

LS RESEARCH LLC
Wireless Product Development
Equipment Calibration

Date : 18-Jun-2015 Type Test : Radiated Measurements Job # : C-2234

Prepared By: Aidi Zainal Customer : Fluke Thermography Quote #: 315160

No.	Asset #	Description	Manufacturer	Model #	Serial #	Cal Date	Cal Due Date	Equipment Status
1	AA 960007	Double Ridge Horn Antenna	EMCO	3115	9311-4138	7/28/2014	7/28/2015	Active Calibration
2	EE 960125	SMA Cable	MegaPhase	NC19-S1S1-236	1GVT4 14032106 001	3/6/2015	3/6/2016	Active Verification
3	AA 960154	2.4GHz High Pass Filter	KWM	HPF-L-14186	7272-02	8/1/2014	8/1/2015	Active Calibration
4	EE 960160	0.8-21GHz LNA	Mini-Circuits	ZVA-213X-S+	977711030	7/28/2014	7/28/2015	Active Calibration
5	EE 960085	N9038A MXE 26.5GHz Receiver	Agilent	N9038A	MY51210148	5/6/2015	5/6/2016	Active Calibration
6	AA 960150	Biconical Antenna	ETS	3110B	0003-3346	1/22/2015	1/22/2016	Active Calibration
7	AA 960078	Log Periodic Antenna	EMCO	93146	9701-4855	1/19/2015	1/19/2016	Active Calibration
8	AA 960144	Phaseflex	Gore	EKD01D010720	5800373	Verification	Verification	System
9	EE 960146	Std. Gain Horn Ant. w/preamp	Adv. Micro / EMCO	WLA622-4 / 3160-09	123001	8/20/2014	8/20/2015	Active Calibration

Project Engineer: Quality Assurance:

APPENDIX B – Test Standards: CURRENT PUBLICATION DATES RADIO

STANDARD #	DATE	Am. 1	Am. 2
ANSI C63.4	2014		
ANSI C63.10	2013		
FCC 47 CFR, Parts 0-15	2015		
FCC Public Notice DA 00-705	2000		
RSS GEN	2014		
RSS 247	2015		

APPENDIX C - Uncertainty Statement

Table of Expanded Uncertainty Values, (K=2) for Specified Measurements

Measurement Type	*Particular Configuration*	*Uncertainty Values*
Radiated Emissions	*3 – Meter chamber, Biconical Antenna*	*4.82 dB*
Radiated Emissions	*3-Meter Chamber, Log Periodic Antenna*	*4.88 dB*
Radiated Emissions	*3-Meter Chamber, Horn Antenna*	*4.85 dB*
Radiated Emissions	*10-Meter OATS, Biconical Antenna*	*4.32 dB*
Radiated Emissions	*10-Meter OATS, Log Periodic Antenna*	*3.63 dB*
Absolute Conducted Emissions	*Agilent PSA/ESA Series*	*1.38 dB*
AC Line Conducted Emissions	*Shielded Room/EMCO LISN*	*3.20 dB*
Radiated Immunity	*3 Volts/Meter in 3-Meter Chamber*	*2.05 Volts/Meter*
Conducted Immunity	*3 Volts level*	*2.33 V*
EFT Burst, Surge, VDI	*230 VAC*	*54.4 V*
ESD Immunity	*Discharge at 15kV*	*3200 V*
Temperature/Humidity	*Thermo-hygrometer*	*0.64° / 2.88 %RH*

APPENDIX D –Bluetooth and WLAN Coexistence

(Information presented below was referenced from TI WILink 8 Software specification, document SWRU423 section 2.10)

Both WLAN and BT operate on a 2.4-GHz ISM band. Allowing the two technologies to work simultaneously, especially when located on the same device, is a challenging task that requires special treatment to keep performance quality on both sides. The advantage of having both Wi-Fi and BT/BLE on a single combo device such as WiLink8.0 provides better correlation between the different IPs to ensure good performance. WiLink8.0 uses a shared antenna for Wi-Fi and BT.

This operation is accomplished by managing a time-division multiplexing (TDM) scheme; transmitting and receiving independent signals over the shared antenna in an alternating pattern, using an external controlled switch.

The WLAN both switches the antenna to the BT IP and protects BT traffic from any WLAN traffic by other devices, using a number of different methods.

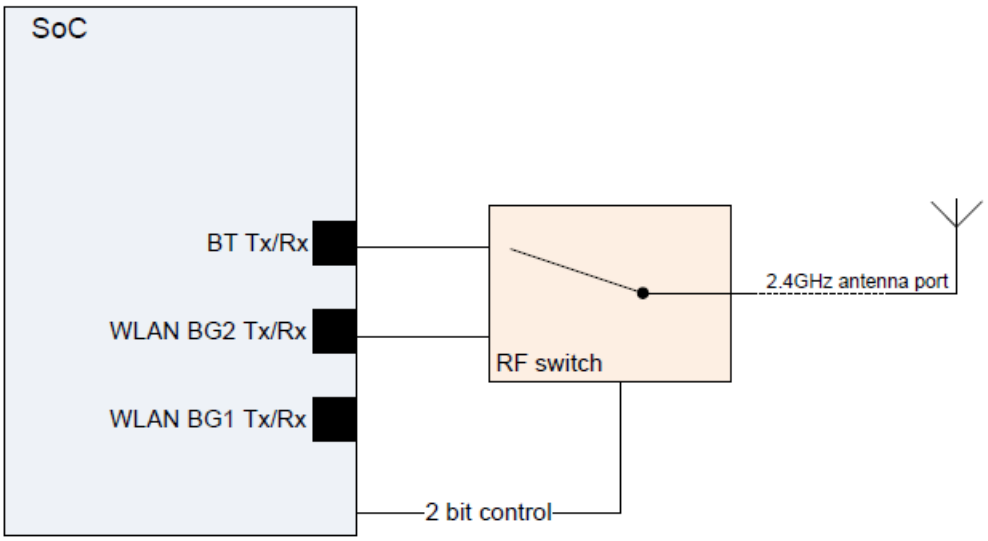


Figure 4. Wi-Fi – BT/BLE Coexistence – Shared Antenna